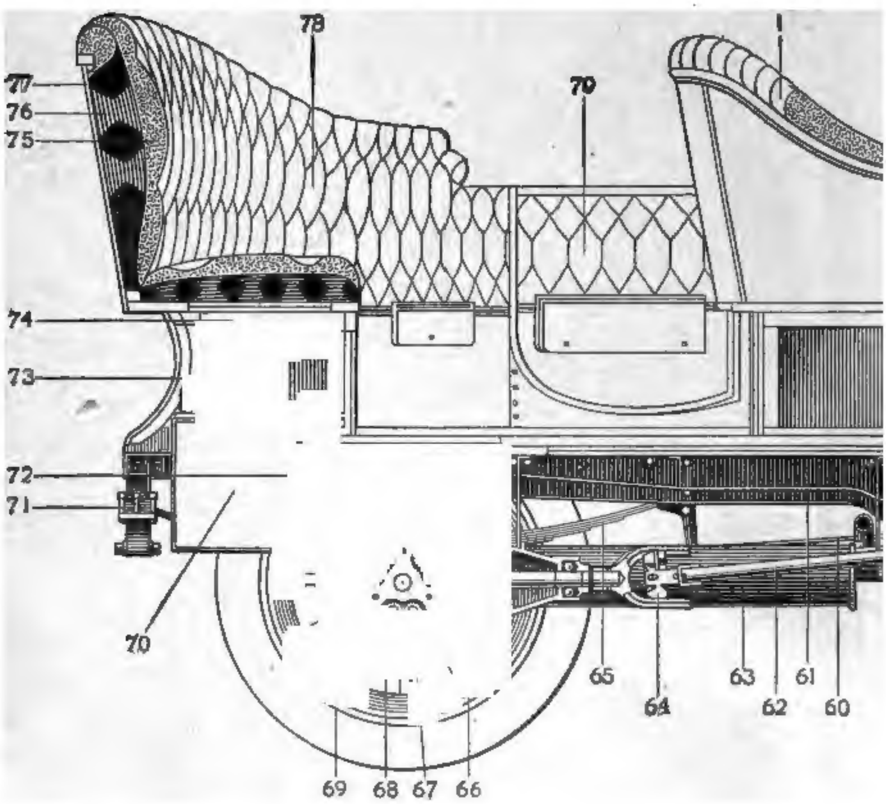
## Plate I.—CROSS-SECTIONAL DIAGRAM OF



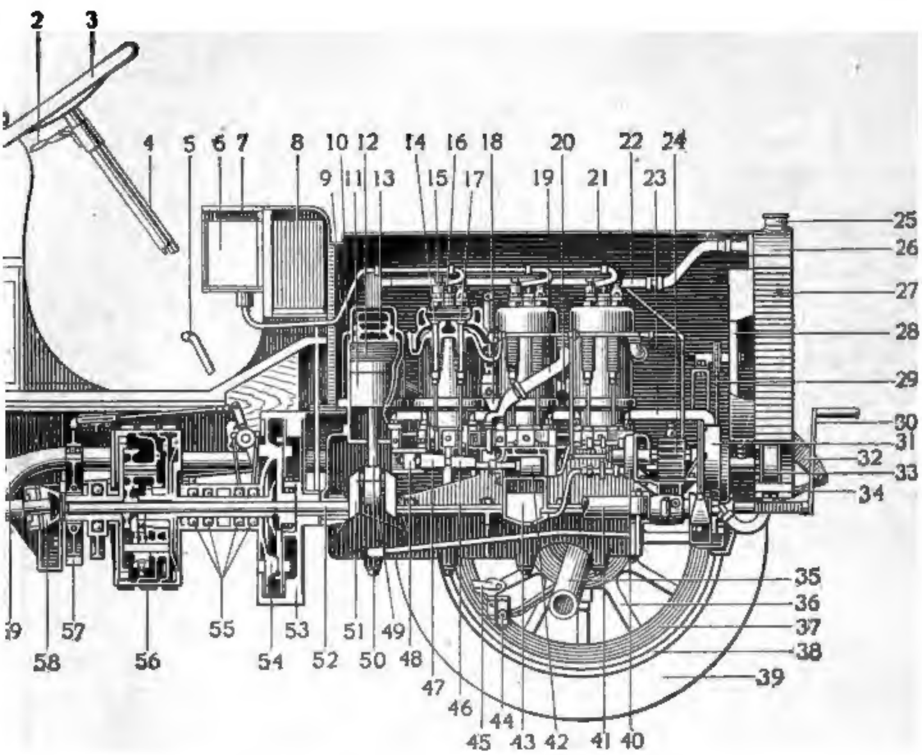

1—Divided front seat for chauffeur.
2—Throttle lever.
3—Steering wheel.
4—Steering pillar.
5—Brake or clutch lever.
6—Spark coil.
7—Spark coil vibrator.
8—Gravity feed gasolene tank.
9—Water jacket wall.
10—Cylinder wall.
11—Piston.
12—Piston ring.
13—Compression chamber.
14—Inlet valve.
15—Spark plug.
16—Relief cock.

17—Exhaust valve.
18—Mixer.
19—Intake pipe.
20—Exhaust pipe.
21—Engine bonnet.
22—Water circulating pipe.
23—Water circulating pipe.
24—Oil pump gear.
25—Radiator cap.
26—Water tank.
27—Radiator.
28—Air cooling fan.
29—Driving chain for fan.
30—Starting crank.
31—Water pump.
32—Forward spring support.

33—Commutat
34—Forward s
35—Tubular fr
36—Spoke.
37—Felloe.
38—Rim.
39—Pneumatic
40—Oil govern
41—Tubular st
42—Oil govern
43—Reserve oi
44—Parallel ro
45—Steering r
46—Cam actu valve.
47—Cam actu

78—Tonneau.

## AMERICAN FOUR-CYLINDER TOURING CAR.




g.
axle.

e.
.ctuating pump.
ame of engine.
iston.
amber.
id.

ng the exhaust

g the inlet valve.

48—Sliding bearing for cam shaft.
49—Connecting rod end.
50—Connecting rod.
51—Crank.
52—Crank shaft of engine.
53—Fly-wheel.
54—Expansion clutch.
55—Ball bearing for transmission shaft.
56—Planetary transmission.
57—Transmission brake drum.
58—Universal joint.
59—Exhaust pipe.
60—Brake rod.
61—Pressure feed pipe for gasolene.
62—Driving shaft.

63—Muffler.
64—Universal joint.
65—Rear side spring.
66—Bevel gear driving pinion.
67—Differential pinion stud.
68—Differential pinion.
69—Differential housing.
70—Main gasolene tank.
71—Rear spring support.
72—Pressed steel side frame.
73—Swinging filler for gasolene tank.
74—Wooden frame of body.
75—Upholstering.
76—Upholstering spring.
77—Aluminum body.

79—Side entrauce door.

*SIXTH EDITION.—REVISED AND ENLARGED.*

# SELF-PROPELLED VEHICLES

A PRACTICAL TREATISE
ON THE
THEORY, CONSTRUCTION, OPERATION,
CARE AND MANAGEMENT
OF ALL FORMS OF
AUTOMOBILES

BY

JAMES E. HOMANS, A. M.

*WITH UPWARDS OF 500 ILLUSTRATIONS AND DIAGRAMS, GIVING THE ESSENTIAL DETAILS OF CONSTRUCTION AND MANY IMPORTANT POINTS ON THE SUCCESSFUL OPERATION OF THE VARIOUS TYPES OF MOTOR CARRIAGES DRIVEN BY STEAM, GASOLINE AND ELECTRICITY.*

THEO. AUDEL & COMPANY
SIXTY-THREE FIFTH AVENUE
NEW YORK
1907

GOTTLIEB DAIMLER

(1834-1899)

INVENTOR OF THE PRACTICAL HIGH-SPEED GASOLINE MOTOR

AND

"FATHER OF THE AUTOMOBILE"

# PREFACE.

Since the publication of the first edition of this book the motor vehicle has passed out of the experimental stage and become a practical reality. That it is now a permanent factor in the world of mechanics, in the domain of travel and recreation, and, latterly also, in commercial life, cannot for a moment be questioned. Already the profession of chauffeur, or automobile driver, has taken rank among skilled callings, affording a new and profitable field of effort. The demand for information of a practical character is insistent. This demand the present revised edition attempts to meet.

The motor vehicle is a singularly complex machine. Its construction and operation involve the consideration of an extensive range of facts in several widely separated departments of mechanical knowledge. The study of its construction and operation is a liberal education in itself. It claims a broad territory.

In order to answer every question that must occur to the practical automobilist, one must produce a whole library of books, rather than a single volume of convenient size. Virtually all such questions may be forestalled, however, by clear explanations of the principles governing the design and construction of the machine, and the most conspicuous situations involved in its operation. It must be said, to the credit of both designer and operator, that questions, perplexities and accidents are far fewer at the present time than several years

ago. This is due to the general dissemination of knowledge of a practical character, also to the fact that the public has learned to consider the motor vehicle seriously, and award it the attention it deserves.

To the vast realm of motordom the present volume essays to discharge the function of a general introduction; a convenient guide book to the intricacies that must inevitably be encountered; a summary of the facts and principles that it is necessary to understand. As far as possible, the presentation of subjects has been determined by consideration of the needs of the man behind the wheel. Irrelevant matters have been eliminated, and attention has been guided toward present conditions, to the exclusion of all that is experimental and obsolete.

Honest criticism and suggestions would be genuinely appreciated by both the author and the publishers, who would esteem it an assistance in the direction of adequately dealing with a subject that is of great interest and still greater importance at the present time.

For kind assistance in the preparation of this new edition the author begs to render thanks to Mr. Charles E. Duryea; to Mr. E. W. Wright; to several leading authorities and manufacturers who have cheerfully furnished information, as acknowledged in the text; to a number of readers of older editions, who have made intelligent suggestions, and asked even more suggestive questions; and to the reading public, whose generous appreciation has encouraged him to attempt improvement on his former efforts.

# GENERAL CONTENTS.

# CHAPTER ONE.

## A BRIEF HISTORY OF SELF-PROPELLED ROAD VEHICLES.

**Requirements for a *Successful Motor* Carriage.**—Even before the days of successful railroad locomotives several inventors had proposed to themselves the problem of a steam-propelled road wagon, and actually made attempts to build machines to embody their designs. In 1769 Nicholas Joseph Cugnot, a captain in the French army, constructed a three-wheeled wagon, having the boiler and engine overhanging, and to be turned with the forward wheel, and propelled by a pair of single-acting cylinders, which worked on ratchets geared to the axle shaft. It was immensely heavy, awkward and unmanageable, but succeeded in making the rather unexpected record of two and a half miles per hour, over the wretched roads of that day, despite the fact that it must stop every few hundred feet to steam up. Later attempts in the same direction introduced several of the essential motor vehicle parts used at the present day, and with commensurately good results. But the really practical road carriage cannot be said to have existed until inventors grasped the idea that the fuel for the engines must be something other than coal, and that, so far as the boilers and driving gears are concerned, the minimum of lightness and compactness must somehow be combined with the maximum of power and speed. This seems a very simple problem, but we must recollect that even the simplest results are often the hardest to attain. Just as the art of printing dates from the invention of an inexpensive method of making paper, so light vehicle motors were first made possible by the successful production of liquid or volatile fuels.

In addition to this, as we shall presently understand, immense contributions to the present successful issue have been made by pneumatic tires, stud steering axles and balance gears, none of which were used in the motor carriages of sixty and eighty years ago. So that, we may confidently insist, although many thoughtless persons still assert that the motor carriage industry is in its infancy, and its results tentative, we have already most of the

elements of the perfect machine, and approximations of the remainder. At the present time the problem is not on what machine can do the required work, but which one can do it best.

**A Brief Review of Motor Carriage History.**—As might be readily surmised, the earliest motor vehicles were those propelled by steam engines, the first attempt, that of Capt. Cugnot, dating, as we have seen, from 1769-70. In the early years of the nineteenth century, and until about 1840-45, a large number of steam

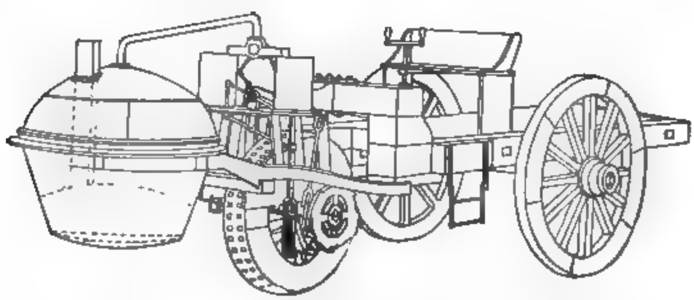


FIG. 1.—Captain Cugnot's Three-wheel Steam Artillery Carriage (1769-70). This cut shows details of the single flue boiler and of the driving connections.

carriages and stage coaches were designed and built in England, some of them enjoying considerable success and bringing profit to their owners. At about the close of this period, however, strict laws regarding the reservation of highways to horse-vehicles put an effectual stop to the further progress of an industry that was already well on its way to perfection, and for over forty years little was done, either in Europe or America, beyond improving the type of farm tractors and steam road rollers, with one or two sporadic attempts to introduce self-propelling steam fire engines. During the whole of this period the light steam road carriage existed only as a pet hobby of ambitious inventors, or as a curiosity for exhibition purposes. Curiously enough, while the progress of railroad locomotion was, in the meantime, rapid and brilliant, the re-awakening of the motor carriage idea and industry, about 1885-89, was really the birth of a new science of constructions, very few of the features of former carriages being then adopted. In 1885 Gottlieb Daimler patented his high-speed gas or mineral spirit engine, the parent and prototype of the wide

variety of explosive vehicle motors since produced and, in the same year, Carl Benz, of Mannheim, constructed and patented his first gasoline tricycles. The next period of progress, in the years immediately succeeding, saw the ascendency of French engineers, Peugeot, Panhard, De Dion and Mors, whose names, next to that of Daimler himself, have become commonplaces with all who speak of motor carriages. In 1889 Leon Serpollet, of Paris, invented his famous instantaneous, or "flash," generator, which was, fairly enough, the most potent agent in restoring the steam engine to consideration as means of motor

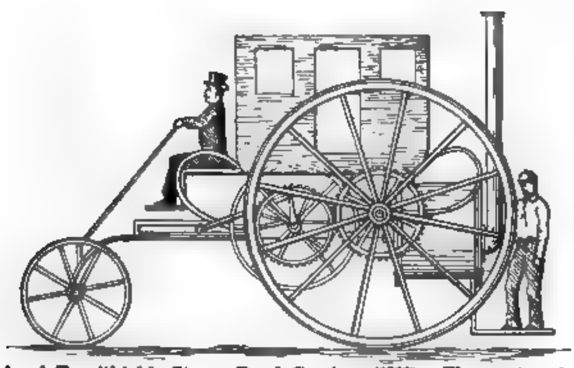


**FIG. 2.—Richard Trevithick's Steam Road Carriage (1803). The centre-pivoted front axle is about half the length of the rear axle. The cylinder is fixed in the centre of the boiler. The engine has a fly-wheel and spur gear connections to the drive axle.**

carriage propulsion. Although it has not become the prevailing type of steam generator for this purpose, it did much to turn the attention of engineers to the work of designing high-power, quick-steaming, small-sized boilers, which have been brought to such high efficiency, particularly in the United States. With perfected steam generators came also the various forms of liquid or gas fuel burners. The successful electric carriage dates from a few years later than either of the others, making its appearance as a practical permanency about 1893-94.

**Trevithick's Steam Carriage.**—In reviewing the history of motor road vehicles we will discover the fact that the attempts which were never more than plans on paper, working models, or downright failures are greatly in excess of the ones even half-

way practical. From within a few years after Cugnot's notable attempt and failure, many inventors in England, France and America appeared as sponsors for some kind of a steam road carriage, and as invariably contributed little to the practical solution of the problem. In 1802 Richard Trevithick, an engineer of ability, subsequently active in the work of developing railroad cars and locomotives, built a steam-propelled road carriage, which, if we may judge from the drawings and plans still extant, was altogether unique, both in design and operation. The body was supported fully six feet from the ground, above rear driving wheels of from eight to ten feet in diameter, which, turning loose on the axle trees, were propelled by spur gears secured to the hubs. The cylinder placed in the centre of the boiler turned its crank on the counter-shaft, just forward of the axle, and imparted its motion through a second pair of spur gears, meshing with those attached to the wheel hubs. The steering was by the forward wheels, whose axle was about half the width of the vehicle, and centre-pivoted, so as to be actuated by a hand lever rising in front of the driver's seat. This difference in the length of the two axles was probably a great advantage to positive steering qualities, even in the absence of any kind of compensating device on the drive shaft. The carriage was a failure, however, owing to lack of financial support, as is alleged, and, after a few trial runs about London, was finally dismantled.

**Gurney's Coaches.**—The Golden Age of steam coaches extended from the early twenties of the nineteenth century for about twenty years. During this period much was done to demonstrate the practicability of steam road carriages, which for a time seemed promising rivals to the budding railroad industry. Considerable capital was invested and a number of carriages were built, which actually carried thousands of passengers over the old stage-coach roads, until adverse legislation set an abrupt period to further extension of the enterprise. Among the names made prominent in these years is that of Goldsworthy Gurney, who, in association with a certain Sir Charles Dance, also an engineer, constructed several coaches, which enjoyed a brief though successful career. His boiler, like those then used in the majority of carriages, was of the water-tube variety, and in many respects

closely resembled some of the most successful styles made at the present day. It consisted of two parallel horizontal cylindrical drums, set one above the other in the width of the carriage, surmounted by a third, a separator tube, and connected together by a number of tubes, each shaped like the letter U laid on its side, and also, directly, by several vertical tubes. The fire was applied to the lower sides of the bent tubes, under forced draught, thus creating a circulation, but, on account of the small heating surface, the boiler was largely a failure. Mr. Dance did much

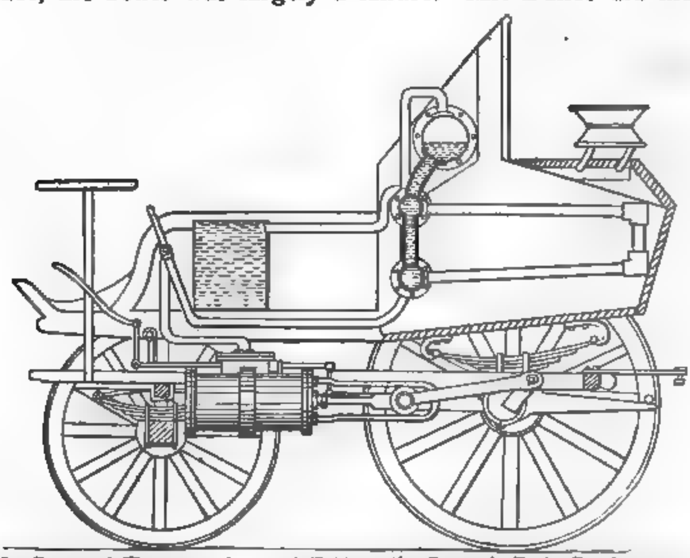


FIG. 3.—Sectional Elevation of one of Goldsworthy Gurney's Early Coaches, showing water tube boiler, directly geared cylinders and peg rod driving wheel.

to remedy the defects of Gurney's boiler with a water-tube generator, designed by himself, in which the triple rows of parallel U-tubes were replaced by a number of similarly-shaped tubes connected around a common circumference by elbow joints, and surmounted by dry steam tubes, thus affording a much larger heating surface for the fire kindled above the lower sides of the bent tubes. Gurney's engine consisted of two parallel cylinders, fixed in the length of the carriage and operating cranks on the revolving rear axle shaft. The wheels turned loose on the axles, and were driven by double arms extending in both directions

from the axle to the felloe of the wheel, where they engaged suitably arranged bolts, or plugs. On level roadways only one wheel was driven, in order to allow of turning, but in ascending hills both were geared to the motor, thus giving full power. In Gurney's later coaches and tractors the steering was by a sector,

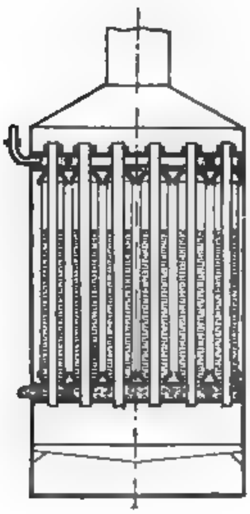


FIG. 4.

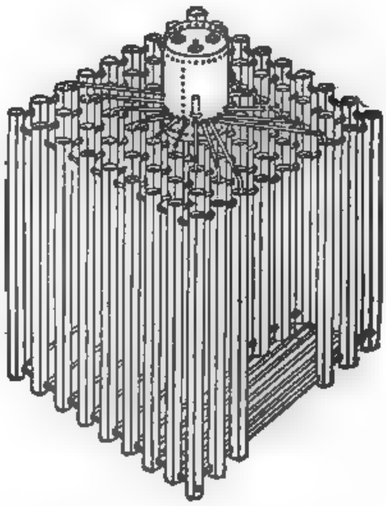


FIG. 5.

FIGS. 4-5.—Improved Boilers for Gurney Coaches; the first by Summers & Ogle; the second by Maceroni & Squire.

with its centre on the pivot of the swinging axle shaft and operated by a gear wheel at the end of the revolving steering post. In one of his earliest carriages he attempted the result with an extra wheel forward of the body and the four-wheel running frame, the swinging forward axle being omitted, but this arrangement speedily proving useless, was abandoned.

**Improvements on Gurney's Coaches.**—Several other builders, notably Maceroni and Squire, and Summers and Ogle, adopted the general plans of Gurney's coaches and driving gear, but added improvements of their own in the construction of the boilers and running-gear. The former partners used a water-tube boiler consisting of eighty vertical tubes, all but eighteen of which were connected at top and bottom by elbows or stay-tubes, the others being extended so as to communicate with a

central vertical steam drum. Summers and Ogle's boiler consisted of thirty combined water tubes and smoke flues, fitting into square plan, flat vertical-axis drums at top and bottom. Into each of these drums—the one for water, the other for steam—the water tubes opened, while through the top and bottom plates, through the length of the water-tubes, ran the contained smoke flues, leading the products of combustion upward from the furnace. The advantage of this construction was that considerable water could be thus heated, under draught, in small tube sections, while the full effect of 250 square feet of heating surface was realized. With both these boilers exceedingly good results were obtained, both in efficiency and in small cost of operation. Indeed, the reasonable cost of running these old-time steam carriages is surprising. It has been stated that Gurney and Dance's coaches required on an average about 4d. (eight cents) per mile for fuel coke, while the coaches built by Maceroni and Squire often averaged as low as 3d. (six cents). The average weight of the eight and ten-passenger coaches was nearly 5,000 pounds, their speed, between ten and thirty miles, and the steam pressure used about 200 pounds.

**Hancock's Coaches.**—By all odds the most brilliant record among the early builders of steam road carriages is that of Walter Hancock, who, between the years 1828 and 1838, built nine carriages, six of them having seen actual use in the work of carrying passengers. His first effort, a three-wheeled phaeton, was driven by a pair of oscillating cylinders geared direct to the front wheel, and being turned on the frame with it in steering. Having learned by actual experiment the faults of this construction, he adopted the most approved practice of driving on the rear axle, and in his first passenger coach, "The Infant," he attached his oscillating cylinder at the rear of the frame, and transmitted the power by an ordinary flat-link chain to the rotating axle. He was the first to use the chain transmission, now practically universal. As he seems to have been a person who readily learned by experience, he soon saw that the exposure of his engines to dust and other abradents was a great source of wear and disablement; consequently in his second coach, "Infant No. 2," he supplanted the oscillating cylinder hung outside by a slide-valve

cylinder and crank disposed within the rear of the coach body above the floor. In this and subsequent carriages he used the chain drive, also operating the boiler feed pump from the cross-head, as in most steam carriages at the present day.

Hancock's boiler was certainly the most interesting feature of his carriages, both in point of original conception and efficiency in steaming. It was composed of a number of flat chambers—"water bags" they were called—laid side by side and intercommunicating with a water drum at the base and steam drum at the top. Each of these chambers was constructed from a flat sheet of metal, hammered into the required shape and flanged along the edges, and, being folded together at the middle point,

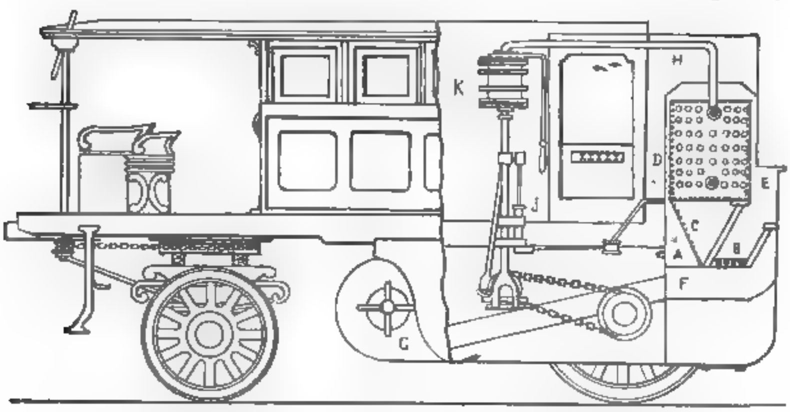



FIG. 6. Part section of one of Hancock's Coaches, showing Engine and Driving Connections. A is the exhaust pipe leading steam against the screen, C, thence up the flue, D, along with smoke and gases from the grate, B. E is the boiler; H the out-take pipe; K the engine cylinder and, J, the water-feed pump; G is a rotary fan for producing a forced draught, and F the flue leading it to the grate.

the two halves were securely riveted together through the flanged edge. The faces of each plate carried regularly disposed hemispherical cavities or bosses, which were in contact when the plates were laid together, thus preserving the distances between them and allowing space for the gases of combustion to pass over an extended heating surface. The high quality of this style of generator may be understood when we learn that, with eleven such chambers or "water bags," 30 x 20 inches x 2 inches in thickness and 89 square feet of heating surface to 6 square feet of grate, one effective horse-power to every five square feet was

realized, which gives us about eighteen effective horse-power for a generator occupying about 11.1 cubic feet of space, or 30 x 20 x 32 inches.

The operation of the Hancock boiler is interesting. The most approved construction was to place the grate slightly to the rear of the boiler's centre, and the fuel, coke, was burnt under forced draught from a rotary fan. The exhaust steam was forced into the space below the boiler, where a good part of it, passing through a finely perforated screen, was transformed into water gas, greatly to the benefit of perfect combustion.

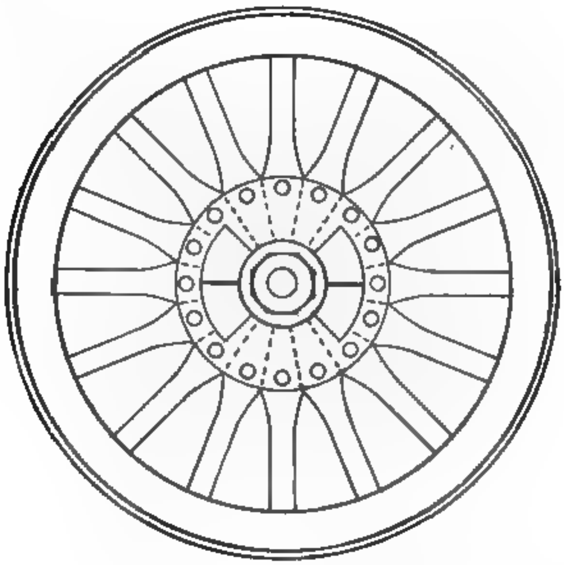


FIG. 7.

FIG 8.

FIG. 7.—Hancock's Wedge Drive Wheel, showing wedge spokes and triangular driving lugs at the nave.
FIG. 8.—One element of the Hancock Boiler, end view.

As early as 1830 Hancock devised the "wedge" wheels, since so widely adopted as models of construction. As shown in the accompanying diagram, his spokes were formed, each with a blunt wedge at its end, tapering on two radii from the nave of the wheel; so that, when laid together, the shape of the complete wheel was found. The blunt ends of these juxtaposed wedges rested upon the periphery of the axle box, which carried a flange,

or vertical disk, forged in one piece with it, so as to rest on the inside face of the wheel. This flange was pierced at intervals to hold bolts, each penetrating one of the spokes, and forming the "hub" with a plate of corresponding diameter nutted upon the outer face of the wheel. The through axle shaft, formed in one piece and rotatable, carried secured to its extremities, when the wheel was set in place, two triangular lugs, oppositely disposed and formed on radii from the nave. The outer hub-plate carried

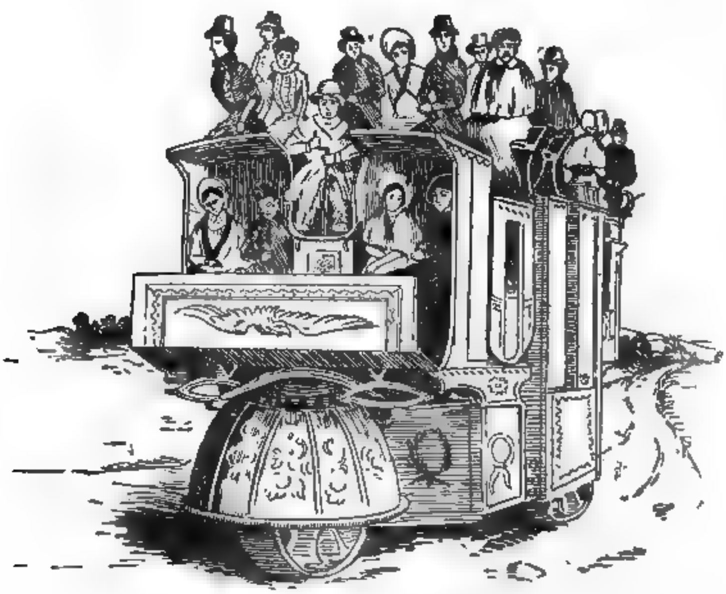


FIG. 9.—Church's Three-wheel Coach (1833), drawn from an old woodcut, showing forward spring wheel mounted on the steering pivot.

similarly shaped and disposed lugs, and the driving was effected by the former pair, turning with the axle spindle, engaging the latter pair, thus combining the advantages of a loose-turning wheel and a rotating axle. Through nearly half of a revolution also the wheel was free to act as a pivot in turning the wagon, thus obtaining the same effect as with Gurney's arm and pin drive wheels. The prime advantage, however, was that the torsional strain was evenly distributed through the entire structure by virtue of the contact of the spoke extremities.

**Other Notable Coaches.**—According to several authorities, only Gurney, Hancock and J. Scott Russell built coaches that saw even short service as paying passenger conveyances—one of the latter's coaches was operated occasionally until about 1857. There were, however, numerous attempts and experimental structures, all more or less successful, which deserve passing mention as embodying some one or another feature that has become a permanence in motor road carriages or devices suggestive of such features. A coach built by a man named James, about 1829, was the first on record to embody a really mechanical device for al-

FIG. 10.—James' Coach (1829), the "first really practical steam carriage built." Drawn from an old wood cut.

lowing differential action of the rear, or driving, wheels. Instead of driving on but one wheel, as did Gurney, or using clutches, like some others, he used separate axles and four cylinders, two for each wheel, thus permitting them to be driven at different speeds. This one feature entitles his coach to description as the "first really practical steam carriage built." Most of the others, if the extant details are at all correct, must have been, except on straight roads, exceedingly unsatisfactory machines at best. According to the best information on the subject, a certain Hills, of Deptford, was the first to design and use on a carriage, in 1843, the compensating balance gear, or "jack in the box," as it was then called, which has since come into universal use on motor vehicles of all descriptions. As for rubber tires, although a certain Thompson is credited with devising some sort of inflatable device of this description about 1840-45, there seems to have

been little done in the way of providing a springy, or resilient, support for the wheels. We have, however, some suggestion of an attempt at spring wheels on Church's coach, which was built in 1833. According to an article in the *Mechanics' Magazine* for January, 1834, which gives the view of this conveyance, as shown in Fig. 9, "The spokes of the wheels are so constructed as to operate like springs to the whole machine—that is, to give and take according to the inequalities of the road." In other respects the vehicle seems to have been fully up to the times, but, judging from its size and passenger capacity, as shown in the cut. it is reasonable to suppose that the use of spring wheels was no superfluous ornamentation. If we may judge further from the cut, the wheels had very broad tires, thus furnishing another element in the direction of easy riding on rough roads.

# CHAPTER TWO.

## THE MAKE-UP OF A MOTOR CARRIAGE.

**Modern Motor Vehicles.**—Like other achievements of modern science and industry, motor road vehicles represent long series of brilliant inventions and improvements in several directions. As now constructed they are of three varieties, according to the motive power employed: those propelled by steam, those propelled by explosive engines, using gasoline or some other spirit, those propelled by electric motors. Considerable has been done in the direction of producing efficient compressed air motors, which have been applied to the propulsion of heavy trucks and street railway cars, but for ordinary carriage service small results have thus far been attained. Some inventors have expended their energies in other directions, and several patents have been granted in the United States for coiled spring and clockwork motors, and even for carriages carrying masts and sails. We are not concerned, however, with such eccentric devices, the aim of this book being merely the discussion and explanation of successful, practical devices actually used in the construction and operation of motor carriages.

**Conditions of Automobile Construction.**—In one way the automobile has a history very like that of the railway carriage. At first both were devised as suitable substitutes for the horse-drawn vehicle, and, as a consequence, began by following certain traditions of construction, which have proved very like hindrances to progress. The first railway passenger coaches were ordinary road wagons, several of which were coupled together, so as to be drawn along a grooved tramway. Later, with the introduction of flanged wheels and heavier constructions, several carriage bodies were mounted on one running truck, which gave the familiar compartment coaches with *vis-a-vis* seats, still used in

England and most of the countries of Continental Europe. Only when the theory of railway car construction departed entirely from the models and traditions of road wagons in the adoption of the American passenger coach, did the day of real progress and comfortable travel begin. In similar fashion many of the greatest constructional problems of automobiles may be most readily solved, both for the designer and the operator, in recognizing the fact that they resemble horse carriages in no other respect than that both have similarly appearing bodies, mounted on four-wheel frames, and run on ordinary highways.

**Essential Elements of an Automobile.**—While in this age of the world it is impossible to assert that any device is perfected, or that any has reached a finality, it is admissible to assume, for practical purposes, that recognized standards of construction are permanent. Undoubtedly, the automobile of the future will possess many features now unsuspected, but it is with the automobile of to-day that we have to do. We will take up the essential features in turn, therefore, describing their construction and explaining their uses. These may be summed, as follows:

1. The power developed by a motor carried on the running gear is applied to the rear wheels, or to a rotating shaft to which they are secured.

2. The two driven wheels must be so arranged as to rotate separately, or at different speeds, as in turning corners. For this reason, the compensation or balance gear is an essential element.

3. The two forward or steering wheels, studded to pivots at either end of a rigid axle-tree, must be arranged to assume different angles in the act of turning, in order that the steering may be positive and certain.

4. The body of the vehicle must be set relatively low, or the wheel-base, the length between forward and rear wheel-centres, must be relatively long, in order to obtain the best effects in traction, steering and safety.

5. The springs must be of such strength and flexibility as to neutralize vibration, absorb jars and compensate any unevenness in the roadway.

6. The distance between the motor and the driven wheels must be fixed by adjustable radius rods, or reaches, in order that the drive may not be interrupted by the vibrations of travel.

7. The wheels must be shod with pneumatic, or other forms of tires, of sufficient resiliency to protect the machinery, running gear and passengers from the jars, otherwise inevitable at high speeds on ordinary highways.

8. Positive and powerful brakes must be provided, in order to secure effective checking of motion, whenever required.

9. All parts must move with as little friction as possible, in order to save power for traction. For this reason, ball or roller bearings are generally used on all rotating shafts of motor carriages.

10. Convenient and efficient means for ready and generous lubrication of moving parts is a constant necessity.

11. Balance of parts and stable constructions are required to reduce wear and friction.

12. Simplicity of structure, ease of handling and repair. These are the prime requisites of the best automobile.

13. All working parts must be of sufficient size, weight and strength to endure the jars of travel, and to be serviceable under all conditions. There may be some advantages in the light constructions, formerly supposed to be essential, but present-day practice recognizes the evident fact that strength and durability are the more important considerations.

## CHAPTER THREE.

### COMPENSATION AND COMPENSATING DEVICES.

**Automobile Driving and Compensation.**—The power of the motor is applied either to the centre-divided rotating rear axle, or to a rotating jack-shaft parallel to it, thence by chain and sprocket to the two wheels, turning loose on a dead rear axle. In both cases the drive is through a device known as the differential or compensating gear. Any device that will admit of a steady drive in straight-ahead running, a difference of speed in the two drive-wheels in turning corners, and a rapid restoration of normal conditions after the turn is completed, is usable for this purpose. There is, however, another necessary function, which may not be omitted,—the differential must also be a "balance gear." That is to say, it must combine with the function of compensation an even or balanced transmission of power to both wheels. Each wheel, so long as it is in motion, must be driven with the same degree of power. At no time, even on short turns when one wheel is stationary, acting as a pivot, is it permissible that, say two-thirds of the power, be sent to one drive-gear, and one-third to the other. The power, transmitted from the centre of the divided axle or jack-shaft, must always be the same in both directions, even though one wheel be stationary.

**Compensation and Balancing.**—For example, the device shown in Fig. 11 is an excellent specimen of a differential or compensating gear that is not also a balance gear. As may be seen, it consists of a large internal gear wheel, C, within which and rotating about the same axis is a smaller external gear or spur wheel, B,—the two engaging the spur pinions, A, A, as shown. The large internal gear turns on the axle of one wheel, the smaller or spur wheel on the opposite one, and power is applied through the pinions hung on radii of the sprocket. The

result was that the power-driven pinions transmitted more power to the internal gear, because of its greater diameter, than to the spur gear, thus giving one wheel a tendency to revolve more rapidly than the other. This device was formerly used on foot-propelled tricycles, and is perfectly suitable for a two-track machine of this description, in which the steering wheel is set directly ahead of one of the drivers, so as to progress on the same track.

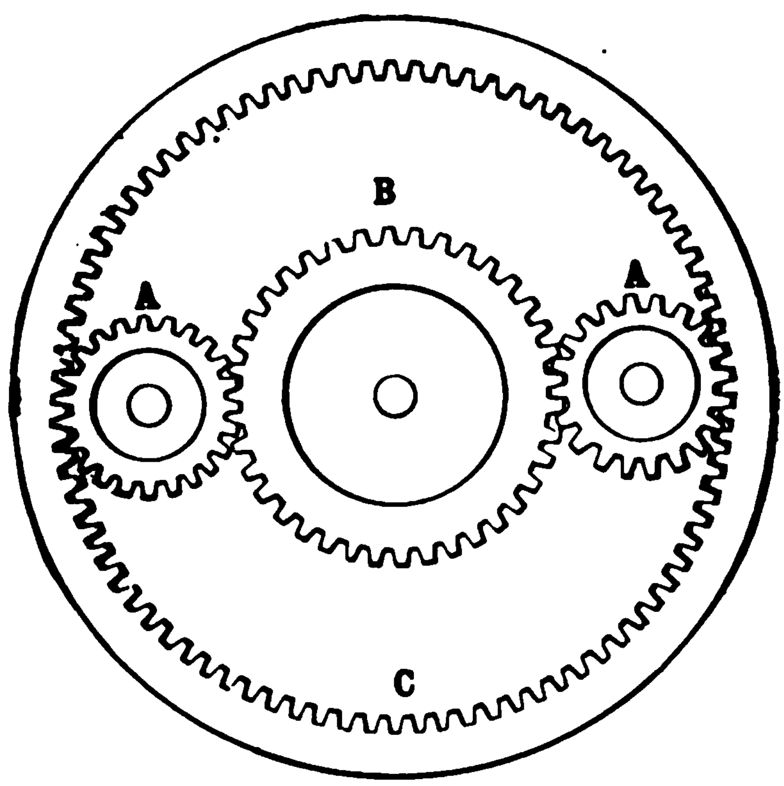
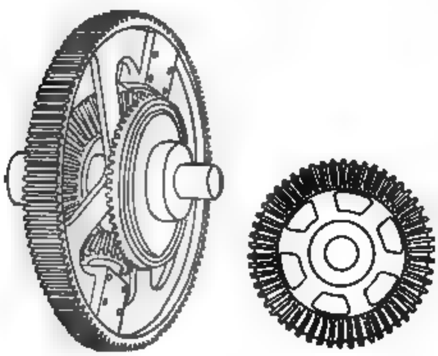



FIG. 11.—A form of Differential Gear formerly used on Tricycles. The studs of the pinions, AA, are set in spokes of the sprocket, turning on their own axes only when either of the wheels of the vehicle, attached respectively to B and C, cease rotating, as in the act of turning.

**Automobile Balance Gears.**—The most familiar form of balance gear for compensating the drive wheels of motor carriages is the bevel. This is the original form of the device, and was used on steam road wagons as early as 1843. As shown in the figure, the sprocket or spur drive wheel has secured to its inner rim several studs carrying bevel pinions, which, in turn, engage a bevel gear wheel on either side of the sprocket. These gear wheels, last mentioned, are rigidly attached on either side to the inner ends of the centre-divided axle-bar, one serving to turn the left wheel, the other the right. When power is applied to the sprocket, causing the vehicle to move straight forward, it may be readily understood that the bevel pinions, secured to the sprocket, instead of rotating, which would mean to turn the drive

wheels in opposite directions, remain motionless, acting simply as a kind of lock or clutch to secure uniform and continuous rotation of both wheels. So soon as a movement to turn the vehicle is made, at which time the wheels tend to move with different speeds, the resistance of the wheel nearer the centre, on which the turn is made, tending to make it turn more slowly than the other, as anyone may readily observe, these pinions begin rotating on their own axes. Thus, while allowing the pivot wheel



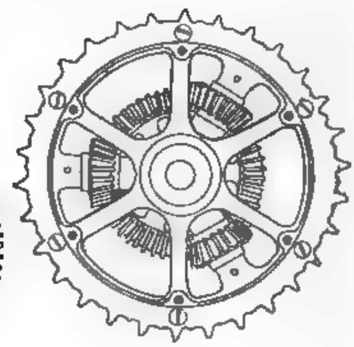


FIG. 12. FIG 13.

FIGS. 12 and 13.—Bevel Gear Differentials. The sprocket gear carries three bevel pinions set on studs on three of its radii. These pinions mesh with bevel wheels on either side, which wheels are attached at the two inner ends of the divided axle shaft. The spur drive has two pinions rotating on radii, and shows the action to better advantage

to slow up or remain stationary, as conditions may require, they continue to urge forward the other at the usual speed. The principle involved in the device may be readily expressed under four heads:

1. When the resistance offered by the two drive wheels and attached gear is the same, as when the carriage is driven forward, the pinions cannot rotate.

2. When the resistance is greater on the one wheel than on the other, they will rotate correspondingly, although still moving forward with the wheel offering the lesser resistance.

3. The pinions may rotate independently on one gear wheel, while still acting as a clutch on the other, sufficient in power to carry it forward.

4. If a resistance be met of sufficient power to stop the rotation of both wheels and their axles, the condition would affect the entire mechanism, and the pinions would still remain stationary on their own axes, just as when in the act of transmitting an equal movement to both wheels.

For light carriage work the sprocket or spur drive generally carries two pinions, as shown in the figure, but in larger vehicles the number is increased to three, four, or six, and the size, pitch

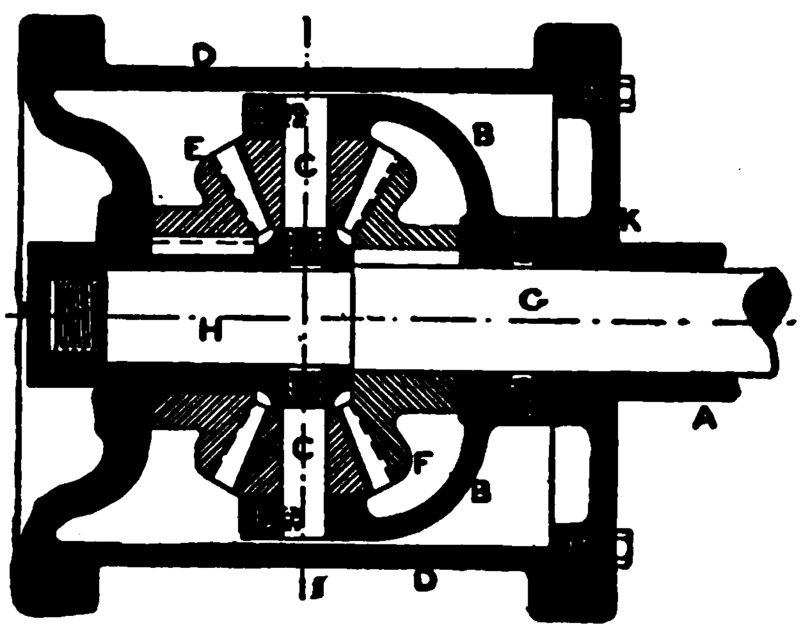



FIG. 14.—The Riker Hub Enclosed Differential. A is the rotating sleeve carrying the drive spur. It is bolted to the yoke carrier, B, and the flange piece, K, as shown. C and C are the studs of the bevel pinions attached to the yoke carrier, B. F is the bevel gear wheel keyed to the rotating through axle shaft, G, whose opposite end is rigidly attached to the other hub. The bevel gear, E, is keyed to the in-flanged portion of the hub, D, turning on the reduced portion, H, of the rotating axle shaft.

and number of the teeth are varied, according to requirements. Of course, it is essential that the equalizing gears be properly chosen for the work they are to perform, in the matter of the number of the pinions and of their teeth, as well as of the metal used, on account of the great strain brought to bear on them. With even the best made bevel-gears there is a danger of end thrust and a tendency to crowd the pinions against the collars, with consequently excessive wear on both. The result is a looseness that demands constant adjustment.

**Spur Compensating Gears.**—In order to avoid the difficulties encountered with bevel gears, spur-gears were invented, and are

now increasing in popularity. In this variety the theory of compensation is the same as with bevel gearing; a divided axle or jack shaft whose two inner ends carry gear wheels cut to mesh with pinions attached to the sprocket pulley. These pinions are, however, set in geared pairs, with their axes at right angles to the radius of the sprocket, which is to say parallel to its axis. As will be seen in the accompanying illustrations, the pinions of each

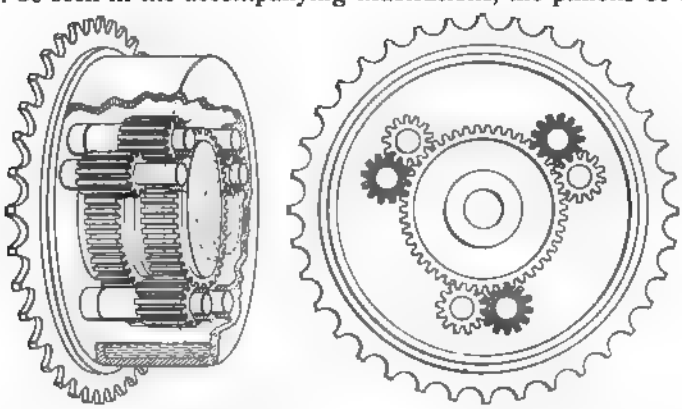


FIG. 15.—One form of Spur Differential or Balance Gear. The two inner ends of the divided axle shaft carry spur wheels, which mesh each with one of every pair of the three pairs of spur pinions shown. As these pinions mesh together both rotate on their axes as soon as turning of the wagon begins.

pair are set alternately on the one side or the other of the sprocket, meshing with one another in about half of their length, the remainder of each being left free to mesh with the axle spurs on the one or other side. The model here has three pairs of pinions, one of each meshing with either of the axle gears. With some differentials the divided axle carries internal gears, with others true spur-wheels. The operation is obvious. When the vehicle is turning, one rear wheel moves less rapidly, causing the pinion with which it is geared to revolve on its mate, which, in turn, revolves on its own axis, although still engaging the gear of the opposite and moving wheel of the vehicle. The motion is thus perfectly compensated, without the wear and thrust inevitable with bevels.

**Disadvantages of a Divided Axle Shaft.**—The practice of dividing the axle or jack shaft at the centre is a source of weakness

which was recognized and provided against long since. Although, theoretically, the shaft is divided at the centre, the construction now usually adopted is to mount one wheel on the axle and the other on a hollow shaft or sleeve which works over it. The solid shaft can then be made as long as the width of the vehicle, the differential gear wheel belonging to it being secured about midway in its length. This hollow shaft or sleeve is about half as long, so that its gear is attached at its inner end and is immedi-

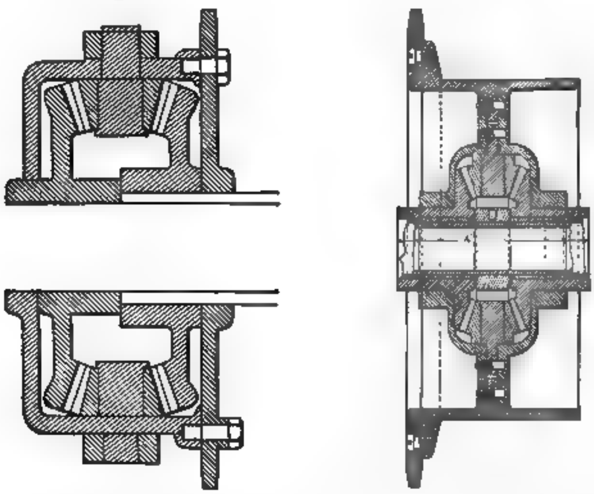


FIG. 16.—Section through the axis of a bevel gear differential train, showing two bevel pinions attached at top and bottom of the sprocket drum, and two bevel gear wheels one on the through axle shaft, the other on a rotating sleeve and through the axis of a bevel gear differential, showing two bevel gears keyed to rotating sleeves over an internal through axle or liner tube.

ately opposite the other, both meshing with the pinions attached to the sprocket. Such a construction involves no other variation from the method of attaching the differential gear-train to the ends of the divided axle than making the eyes of the two gear wheels of different diameters, so as to fit the axle shaft, on the one side, and the hollow axle, or sleeve, on the other. The sprocket is then inserted between them, being held in position by the meshing of the axle gears with the pinions, itself turning loose on the solid through shaft. The inner solid axle shaft is secured in position by suitable collars.

**Through Axle Shaft and Liner Tube.**—Another typical method for securing the strength and solidity of a through axle shaft is to attach both wheels to hollow axles of the same diameter, each of which carries on its opposite or inner end the gear wheel of the differential train. Another tube, called the "liner tube," of the same length as the width of the vehicle, is then inserted in the hollow axles, and the two are brought together so as to bear upon a collar secured to the centre of the liner tube. The sprocket and differential pinion train are inserted and held in place in a fashion similar to that used in the previous device, the inter-meshing of the bevels serving to support it.

With either of these arrangements it is customary to place the differential nearer one wheel.

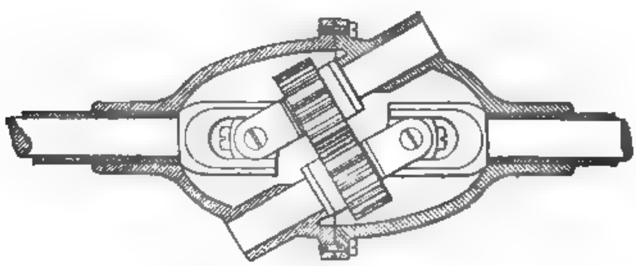


FIG. 17.—A Universal Joint Differential. The sprocket or spur drive turns the sleeve which holds the gear case here shown in section. So long as travel is straight ahead neither pinion rotates on its axis, but as soon as a turn is made rotation begins, thus allowing compensation of the motion of the two wheels of the wagon.

# CHAPTER FOUR.

## THE TRANSMISSION OF POWER.

**Types of Power Transmission.**—In the transmission of power to the driven wheels several methods are followed in practice. These vary according to the size and weight of the vehicle and the character of the motor, also according to the individual preference of the designer. One system is to be preferred to another on account of real or supposed strength and reliability, or of its efficiency in economizing power. Thus it is that a certain system of transmission, declared by one builder fit only for light cars, is used by another on heavy ones, and the opposite is also the case.

At the present time, we may distinguish seven varieties of transmission:

1. By chain and sprocket connection from the main shaft—in gasoline carriages, from the second shaft—direct to the differential on the rear axle.

2. By chain and sprocket to each rear wheel separately, from a transverse jack shaft, driven direct from the motor and carrying the differential drum.

3. By longitudinal propeller shaft from the motor to the rear axle, power being transmitted by bevel gears to the differential drum. This method of driving is usually followed between the motor shaft and the jack shaft in the type of transmission just described.

4. By spur gear connections from the motor shaft to the differential drum on the rear axle, as on a few gasoline carriages, some cycles and on nearly all electric vehicles.

5. By spur connection to an external or internal gear on each of the rear wheels from a transverse differential shaft, as in some electric vehicles.

6. By spur connection to an external or internal gear on each of the drive wheels, between each wheel and a separate motor, without using a differential device of any kind, used only on electric vehicles.

7. By using the hub of each wheel as one element of the motor; as in the so-called electric "hub motors," or in cycles where the motor is enclosed within the body of a suspended wire

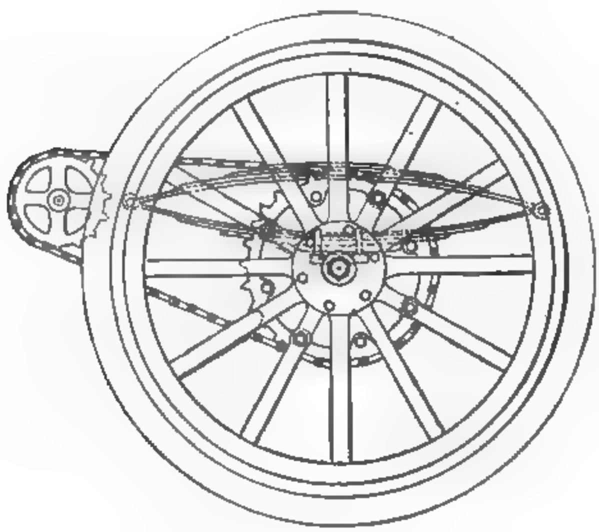
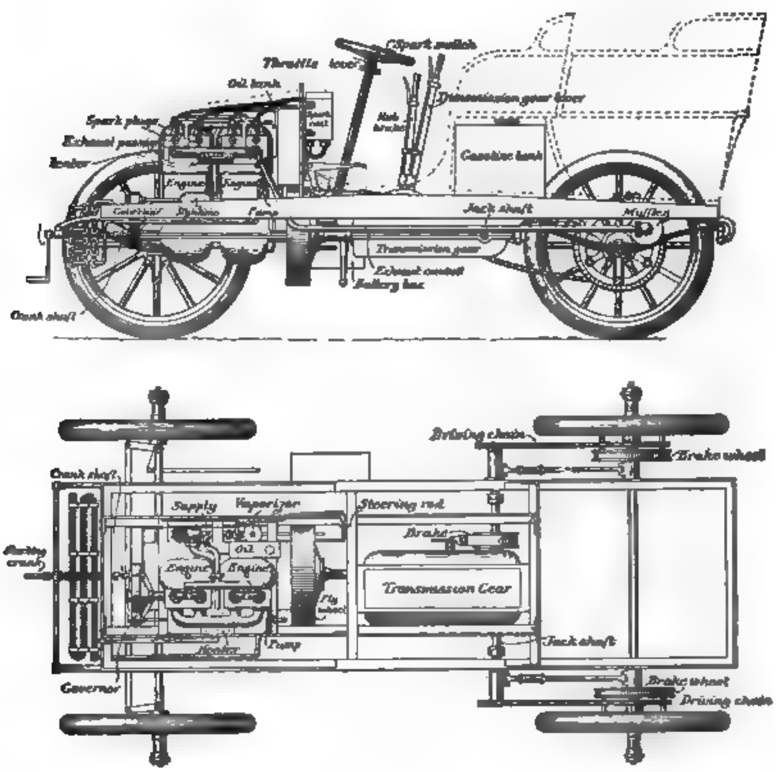


FIG. 18.—Single wheel of a type of car having double-chain drive from a jack-shaft parallel to the dead rear axle

wheel, as in a cage. A similar device has been tried for steam carriages, but without conspicuous success.

Direct drive by a crank on the drive wheel, axle or jack shaft, has been tried in recent times only on one or two bicycles, among them the Holden. The so-called "direct drive" claimed for some modern steam carriages, is really a spur drive; one spur carrying the crank pins of the engine, the other being hung on the differential axis.

**Chain and Sprocket Drive.**—The chain drive may safely be called typical, being used at the present time more frequently than any other method. On some large vehicles of early design a single chain connection between the motor main shaft, or the transmission gear, and the differential sprocket on the rear axle, was frequently employed. However, it was early found entirely




FIGS. 19, 20.—Part Sectional Elevation and Plan of the Riker-Locomobile Chassis, showing arrangement of jack-shaft, or countershaft, and double chain drive.

unsuitable for any except the lighter types of vehicle. With heavy cars of long wheel base, as at present constructed, it would be absurd.

**Jack-Shaft and Separate Wheel Drive.**—This construction is found on practically all heavy cars using chain drive. Briefly described, the system includes:

1. A transverse centre-divided jack-shaft driven direct from the motor, or through the transmission gear, by bevels to the differential drum.

2. A sprocket at each end of the jack-shaft for providing chain connection to the hub of each rear wheel.

3. Driven wheels turning loose at the ends of a dead axle-tree, as in a horse carriage, each being driven by a separate chain on a sprocket secured to its hub.

The advantages that may be found in this arrangement are:

1. The superior strength and rigidity of construction to be found in an undivided rigid rear axle.

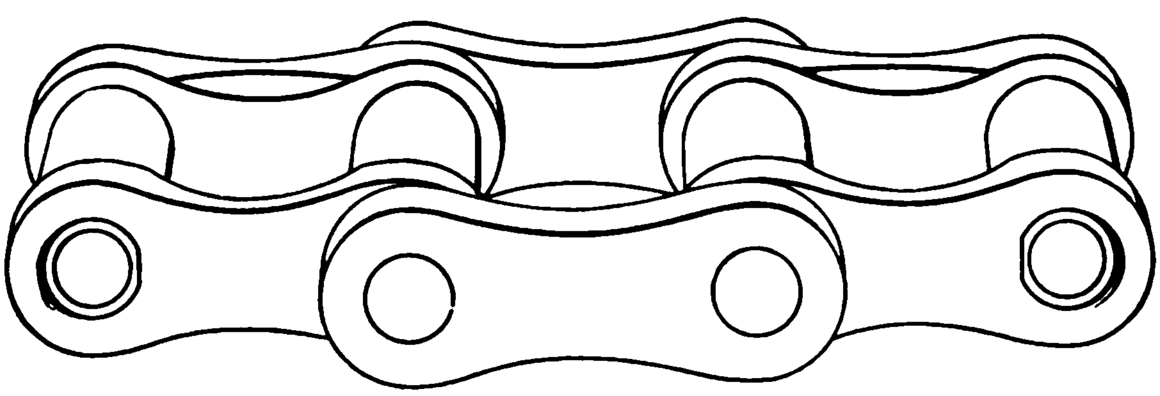


FIG. 21.—Section of a driving chain, showing arrangement of the rollers and side links.

2. The use of shorter chains, involving a greater immunity from ordinary chain troubles, and greater ease of adjustment.

3. Greater ease in removing and repairing the driven wheels.

4. Steadier and better-balanced driving, with a corresponding economy of power.

**Troubles with Two-Chain Drive.**—Formerly, the use of two chains was found to involve more noise and clatter than is found with one. However, with roller chains, now in nearly universal use on motor vehicles, this annoyance is greatly reduced. Much noise is caused with a loose chain by the jumping of links missing a tooth of the sprocket.

**Driving Chains and Their Use.**—Two varieties of sprocket driving chain are used on motor vehicles:

1. Roller chains.
2. Block chains.

Both have their advocates, who argue variously the advantages of superior strength or superior driving qualities and noiselessness.

The block chain is made of a series of blocks, properly shaped to fit the periphery of the sprocket, each joined to similar blocks before and after by side links bolted through the body of the block.

The roller chain is made of a series of pairs of rollers, known as centre blocks, similarly joined by side links. Each roller rotates loose on a hollow core, which is turned to smaller diameter at either end, to fit a perforated side piece joining the rollers into pairs. The side-links are set over these side pieces and bolted in place through the cores.

In operation, a block chain with generous slack is liable to meet the sprocket with a continual clapping that at high speed becomes a continuous rattle. The roller chain is largely immune from this trouble. Furthermore, being obviously easier in operation, it economizes power. Some authorities estimate its efficiency in driving as high as 98 per cent. under favorable conditions.

**Strength of Driving Chains.**—In point of strength a comparison between block and roller chains of the same sizes is interesting, as showing the insuperable superiority of the latter variety. The following tables are supplied by a prominent chain and gear manufacturer. For Diamond non-detachable B-block chains:

| PITCH | WIDTH | BREAKING LOAD |
|---|---|---|
| 1″ | 5/16, 3/8 or 1/2 | 1,600 lbs. |
| 1″ | 5/16, 3/8 or 1/2 | 2,500 " |
| 1½″ | ½ | 5,000 " |

For three different makes of roller chains, the following figures are given:

| PITCH | WIDTH | DIAMETER OF ROLLER | BREAKING LOAD |
|---|---|---|---|
| ½" | ⅛, 3/16, or ¼ | | 1,200 lbs. |
| ⅝" | ⅛, 3/16, or ¼ | | 1,400 " |
| ¾" | 5/16 or ⅜ | 15/32 | 4,000 " |
| 15/16" | ⅜ or ½ | 9/16 | 4,500 " |
| 1" | ⅜ or ½ | 9/16 or ⅝ | 5,000 or 5,500 " |
| 1¼" | ½ or ⅝ | ⅝ or ¾ | 5,500 to 7,500 " |
| 1½" | ⅝ or ¾ | ¾ to ⅞ | 12,000 " |
| 1¾" | 1 | 1 | 19,000 " |
| 2" | 1¼ | 1⅛ | 25,000 " |

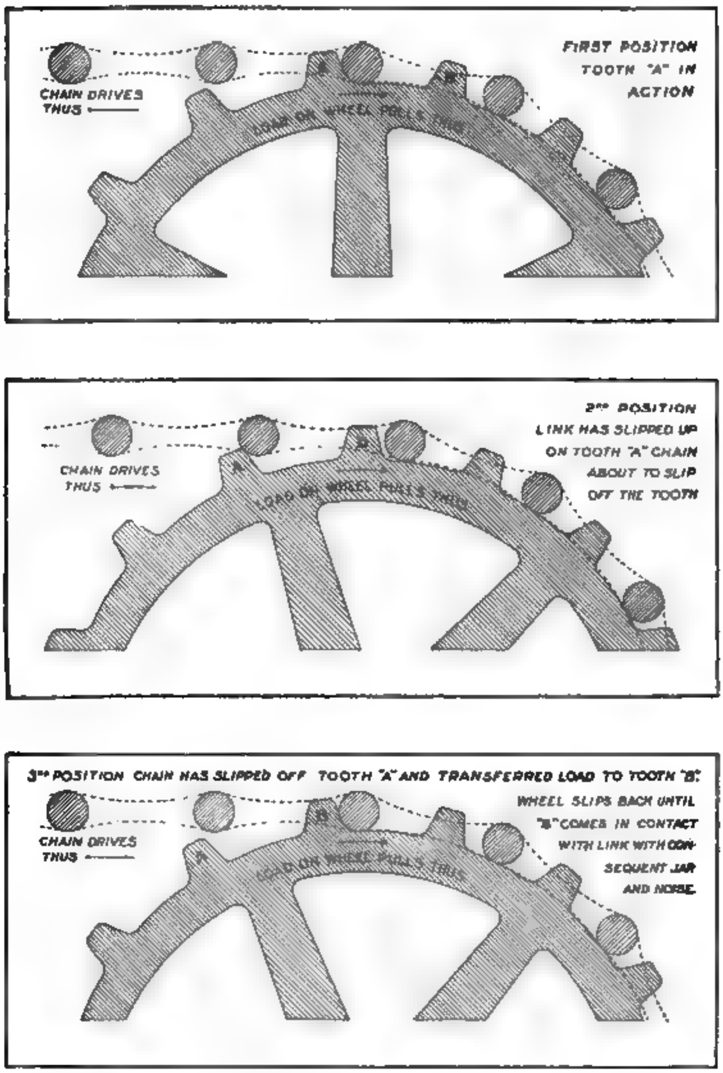
For the sizes of chain here specified, the breaking strength of the roller chain, or the average limit of its pulling power, is shown to be between ½ and ⅔ greater than that of the block chain.

Under ordinary conditions of use, the safe working load of a chain varies between 1-10 and 1-40 the tensile strength. This latter is generally very high. According to the statements of a prominent chain manufacturer:

"A ¾ inch pitch roller chain has sufficient strength to drive a six-ton truck a number of hours. The breaking of this chain will not occur until the pitch of chain and sprocket has elongated, or they become unlike; then the chain climbs the teeth, which act as wedges, exerting enormous strain, quickly wrecking the chain."

**Operation of a Driving Chain.**—The same authority explains that:

"The rivets of a chain act as a number of auxiliary shafts, and operate under friction in the same manner, but with less favorable conditions than the shaft that drives them. In order to adapt the chain to the load it must carry, he recommends larger sizes than are at present generally used, explaining that the limit of fatigue should approach closely the ultimate strength, and, with these factors attained, the size of chain should be selected which permits sufficient rivet wearing surface. This additional size and weight is objected to by automobile builders, on account of what they term 'clumsiness, weight and expense.'"




Figs. 22, 23, 24.—Diagrams illustrating the operation of driving with a roller chain and sprocket.

**Chain and Bevel Transmissions.**—Claiming that chain-transmission of proper design excels in every particular, he asserts that, "a few makers, rather than follow the necessary natural laws of mechanics, have condemned chain transmission and adopted bevel gears, a form of power transmission which engineers generally consider as inefficient on account of loss of power and wear."

**Proportions of the Sprocket.**—In the design of a chain-transmission system, the proportions of the sprocket are important. According to reliable data:

"The thickness of the sprocket at pitch line should be from 1/32 to 1/16 inch less than the length of the roller, according to pitch of chain. Thickness of tooth on outside diameter should be ½ the length of roller."

The number of teeth is as important a consideration on a sprocket as on a gear wheel. In both cases twelve teeth form the average of good efficiency. This is explained in the following quotation:

"The most satisfactory results are obtained by the use of sprockets having twelve teeth or over. A smaller number may be used, but at a sacrifice of efficiency by elongation from wear of chain, wear of sprockets, and loss of power, experience demonstrates that eight-tooth sprockets are chain-wreckers and power-consumers. Nine teeth will give only fair results, and ten and eleven teeth can only be termed satisfactory when the speed is not high and the conditions of operation are unusually favorable."

**Sprocket Teeth and Chain Links.**—A good rule to observe in practice is to see that the "number of teeth in the sprockets should be prime to the number of links in the chain, or, at least, that the latter should not be divisible by the former, so that each tooth of the sprocket in turn shall engage every link in the chain, thus ensuring even wear."

**Pitches of Chain and Sprocket.**—It is impracticable to so design a driving sprocket that the chain rollers shall fit snugly between the teeth. The following quotation from an English authority explains the situation:

"A chain can never be in true pitch with its sprocket. A pair of spur gears tend—to a certain extent—to wear into a good running fit with each other, but a chain, if made to fit its sprocket when new, does not continue to do so a moment after being made, as wear at once throws it out. This being so, it must be put up with, and involves the consequence that a chain can only drive with one tooth at a time, supplemented by any frictional "bite" the other links may have on the base of the tooth interspaces. If the chain be made to fit these accurately, as in Fig. 25 (taking a roller chain in illustration), it is obvious that the least stretch will cause the rollers AA to begin to ride on the teeth as at BB. If, however, the teeth be made narrow compared with the spaces between the rollers, a considerable stretch may occur without this taking place. The roller interspaces, then, should be long, to permit the teeth to have some play in them, while retaining sufficient strength, as shown in Fig. 25 at B.

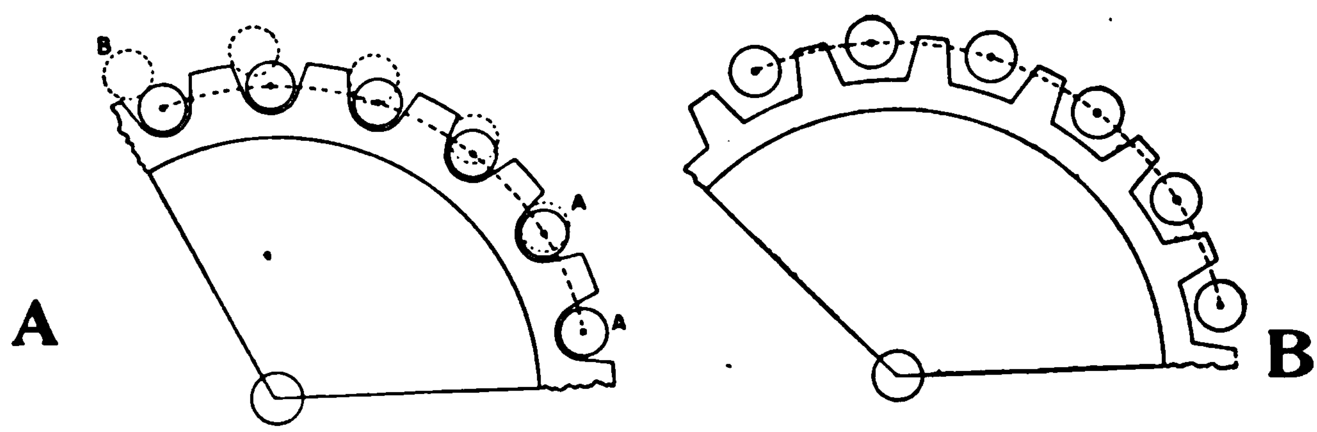



FIG. 25.—Diagrams showing the behavior of a chain on a sprocket of equal pitch, and on one of properly unequal pitch.

"In order that the driving sprocket may receive each incoming link of the chain without its having to slide up the tooth-face, it should be of a somewhat longer pitch than its chain, the result being that the bottom tooth takes the drive, this being permitted by the tooth-play shown in Fig. B. This difference, of course, gradually disappears as the chain stretches. The back wheel sprocket, on the other hand, should take the drive with its topmost tooth, and hence should be of slightly less pitch than the chain, but as the pitch of the latter constantly increases, it may be originally of the same pitch. The only remaining point with regard to design, and one which the owner of a car may easily ensure, is that the number of teeth in the sprockets should be prime to that of the links in the chain, or at least that the latter should not be divisible by the former, so that each tooth in turn of the sprocket shall engage every link in the chain, thus ensuring equal wear."

Even with the best designed sprocket, as each tooth in turn passes out of engagement with the chain, the next roller must be drawn forward through an appreciable distance before engaging a

tooth. This causes the snap and rattle, always noticeable in chain-driven vehicles, and is an important factor in waste of driving power. To remedy such defects some have suggested the use of the self-adjusting silent gear chain, so successfully used in other branches of mechanical science. The difficulty here, however, is that such chains must be drawn tighter than those generally used on sprockets, and, unless thoroughly encased, are liable on an automobile to gather dust and grit, which greatly reduce their durability.

**Care of Chains.**—The principal points to be observed in the use and care of sprocket driving chains are:

1. To maintain the proper tension in order to avoid whipping—which is liable to result in snapping of the chain, particularly a long one—and, at best, involves a loss of driving efficiency. The chain should not be drawn tight, lest a similar disaster result. Some slack must always be allowed.

2. The two sprockets should always be kept in perfect alignment. In the case of double-chain drive from a counter-shaft parallel to the rear axle, care should be exercised to maintain the parallelism, even preferring a somewhat loose chain to a tight one that strains the counter-shaft.

3. If a link shows signs of elongation it should be replaced by a new one at once.

4. Whenever the chain is removed for cleaning or other purpose, it should be carefully replaced, so as to run *in the same direction,* as formerly, and with the same side up. Never turn the chain around or reverse its direction between the sprockets.

5. A new chain should not be put upon a much-worn sprocket.

6. A conspicuous difficulty involved in the use of driving chains is the liability to clog and grind with sand, dust and other abradents. A chain should be occasionally cleaned, therefore, and, what is more important, should be carefully rubbed with graphite preparation, which is the best lubricant for the purpose,

and fills the chinks otherwise open to receive dirt. Furthermore, it prevents dust from adhering to the surface of the chain.

7. After steady use for a more or less extended period, the chain should be removed and thoroughly cleaned. The most approved method is as follows:

**Cleaning the Drive Chain.**—After removing the chain, cleanse first in boiling water, then in gasoline, in order to remove all grease and dirt whatever. Any break or defect may now be plainly discovered, and should be remedied by inserting new links for those disabled. The common practice is then to boil the chain for about half an hour in mutton tallow, which is thereby permitted to penetrate all chinks between rolling surfaces, forming an excellent inside lubricant. After boiling, the chain is hung up until thoroughly cool, at which time the tallow is hardened. It may then be wiped off clean and treated with a preparation of graphite, or a graphite-alcohol solution on its inner surface.

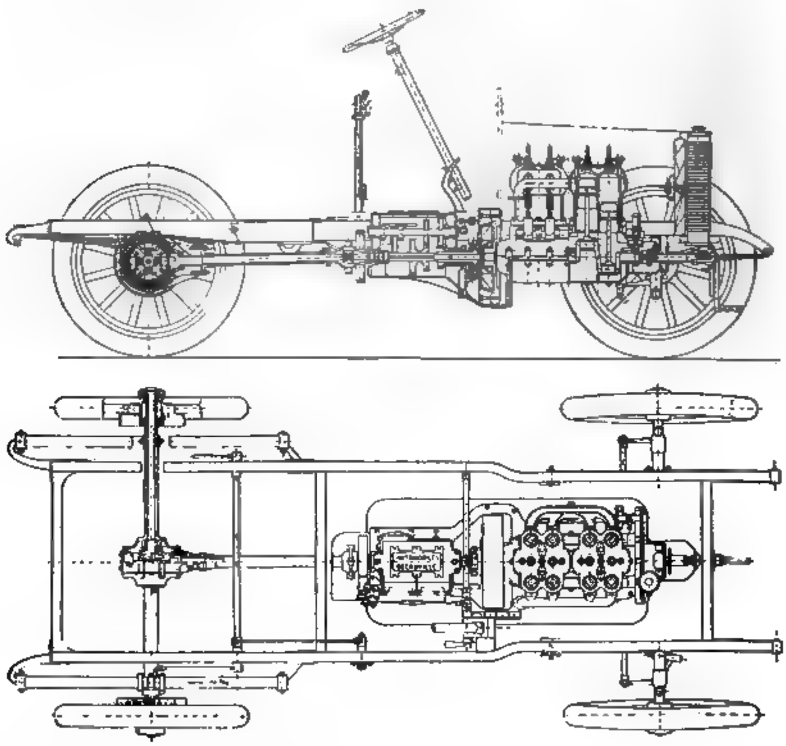
Some authorities recommend that the chain, after it is cleaned, should be soaked, first, in melted paraffin for an hour at least, and then in a mixture of melted mutton tallow and graphite. After each soaking, it is dried and wiped clean.

With either process, a daily application of graphite chain preparation is most desirable.

**Looseness of Chains.**—On the point of chain adjustment, the authority quoted above writes as follows:

"Shedding of chains is generally brought about either by excessive looseness or want of alignment between the sprockets and back chain wheels; a sufficient transverse rounding of the tips of the teeth is advisable to diminish the chance of it. A shrowding or flange on each side of the teeth for the side plates of the chain to bear on is certainly desirable, as diminishing the wear on the rollers and giving a certain increase of frictional drive; but it is not always provided. It may be here noted, as a reply to a question occasionally asked by untechnical drivers, that *where there is a differential on the countershaft an inequality in the tightness of the chains does not prevent each of them taking its share of the driving;* and it is more important that the parallelism of the countershaft and back axles shall be maintained than that the chains should be kept equally tight at the sacrifice of this."

**Propeller-Shaft Transmission.**—Transmission of power by propeller shaft, through bevel gears, to the rear axle, has been adopted by a number of designers, and seems to be gaining favor. It would seem to be the logical outcome of the jack-shaft and double chain system already noticed, since the bevel drive is



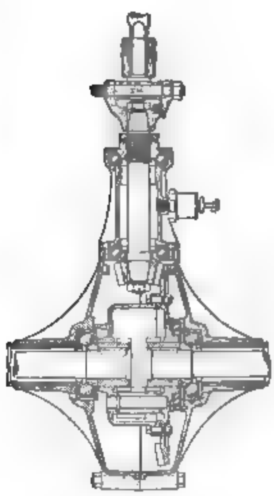
FIGS. 26, 27—Part Sectional Elevation and Plan of the Decauville Car, showing general arrangement of a propeller shaft drive through bevel gears to the rear axle.

direct to the rear axle, instead of to the transverse jack-shaft. There are several problems and difficulties involved, however, that do not appear in other types of transmission.

1. There is naturally greater opportunity for end-thrusts on the rear axle than on a jack-shaft, with a commensurate wear on the parts and danger of breakage.

2. Although a universally jointed shaft connects the motor and the driving bevel, the maintaining of perfect steadiness is difficult and various lateral stresses, notably the tendency of the pinion to climb upward or downward over the teeth of the gear, according as the motion is straight ahead or reversed.

As a consequence of these conditions, ball bearings are provided to take the thrust of the large bevel gear on the axle-shaft.



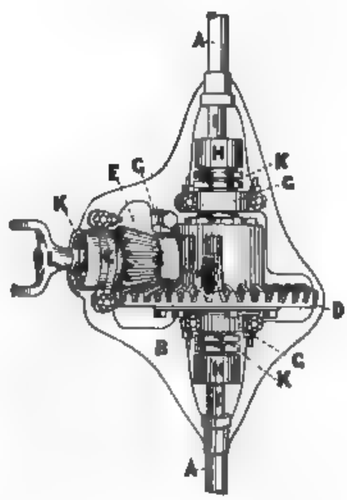



FIG. 28.—Sectional diagram of the bevel-drive of the Pierce Car, showing arrangement of the propeller shaft and location of the thrust bearings.

FIG. 29. Bevel Driving Apparatus of the Peerless Car, A and B, sleeve and case for axles and gears; D, the driven gear, E, driving pinion; G, ball bearings on E H, H, universal couplings on the differential; K, K, K, adjustments; L, yoke for flexible driving shaft.

A slip-joint, in addition to the universal coupling on the propeller-shaft, compensates for the varying distance between the speed gear and the axle, under the rise and fall of the springs. In the Packard, and one or two other cars, approximate steadiness of the driving pinion is attained by placing the speed gear directly in front of the rear axle.

**The Haynes Propeller Drive.**—The Haynes carriage embodies an interesting variation on the common types of bevel drive, having as the driven gear a kind of dished crown gear or sprocket, with teeth around the inturned edge, and, as the driving pinion a roller gear, in which a number of rollers, inclined inward from the periphery, serve instead of teeth. The rotary tendency of the differential case, under stress of the driving pinion, is avoided by the use of a vertical stay-bar projecting through a square yoke in a cross bar above the spring, which serves to direct the stress upward, thus removing all strain from

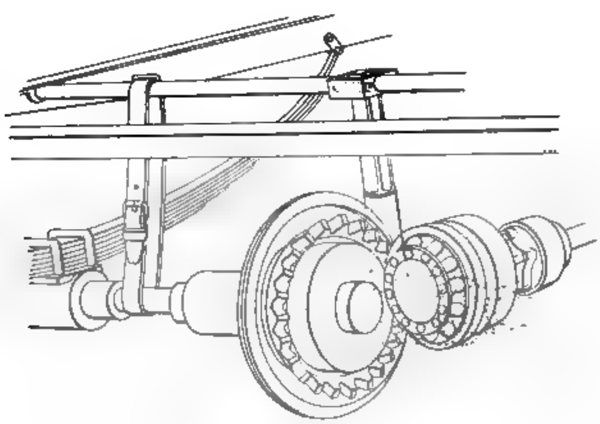


FIG. 30.—The Haynes-Propeller-Shaft Drive, which marks a decided improvement on common types of bevel drive.

the axle casing. Instead of the usual slip-joint, consisting of a sliding square-section shaft, a "four-pronged joint" is used. In this arrangement a flanged hub is keyed to the driving shaft, and carries four steel pins, which project forward, entering four holes in the body of the universal joint. Thus the torque exerts no torsional stress other than a shearing force upon the pins, which has been proved of no serious importance. The advantages claimed for this device are:

1. Superior strength, as found in the comparison between the long, narrow teeth of a bevel gear and the short, thick teeth of the Haynes sprocket.

2. Elimination of thrust, in the fact that two rollers are always in full engagement with the sprocket, one always entering a hollow as another passes out of engagement.

3. Silent operation, by combining the advantages of bevel and roller chain drive, while avoiding their inherent difficulties.

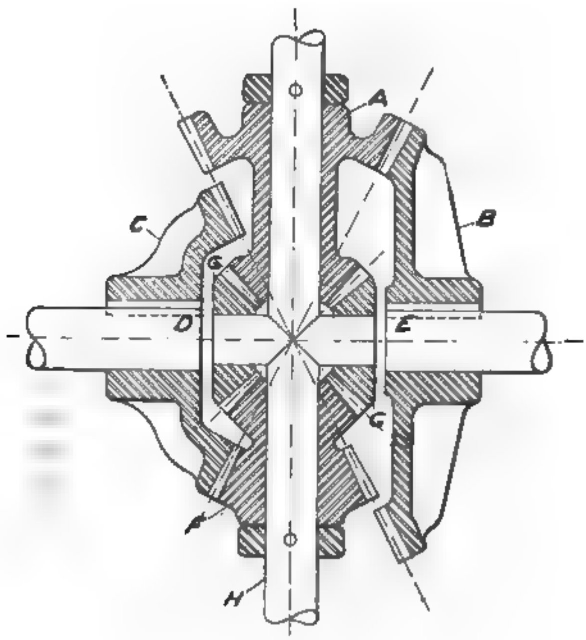



FIG. 31.—Plan view of a combined differential and transmission gear, representing a type of construction that embodies the advantages of the bevel-gear drive, while avoiding its deficiencies.

**Daimler's Differential Transmission.**—Closely akin to the common bevel drive is a combined transmission and differential gear designed some years since for use on heavy trucks. It seems worthy of notice on account of several original features. As shown in an accompanying diagram, H is the driving shaft, which drives the bevels, B and C, on the two half axles, D and E, through the bevels, A and F. These last are loose on H, being held rigid by intermeshing with pinions, G, G, carried on a cross

arm on H. Differential action between the two rear wheels is obtained when, in turning, B or C offers resistance to the rotation of A or F, such resistance causing the pinions, G and G, to rotate on their axes, compensating the movements of the two wheels, as in other differential gears. This device allows the use of dished wheels, since, as is evident, the gears, B and C, may be inclined at any desired angle together with their axles, by merely altering the angles of the bevels. The ratios of the gears, B and A, and C and F, being the same, the balance of speed and power in transmission is maintained.

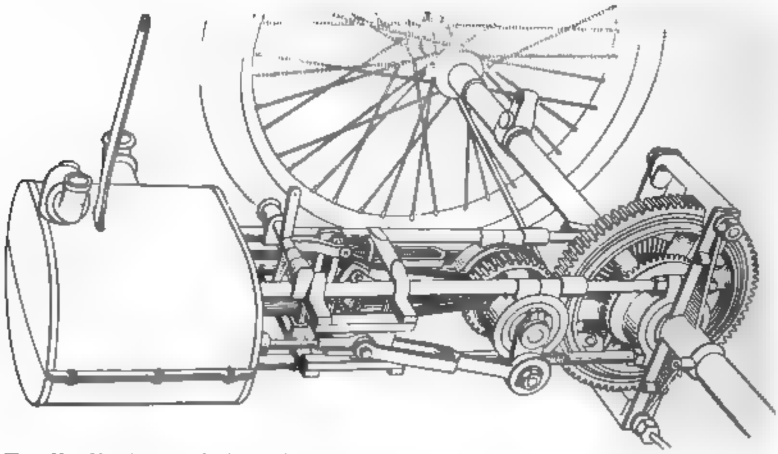
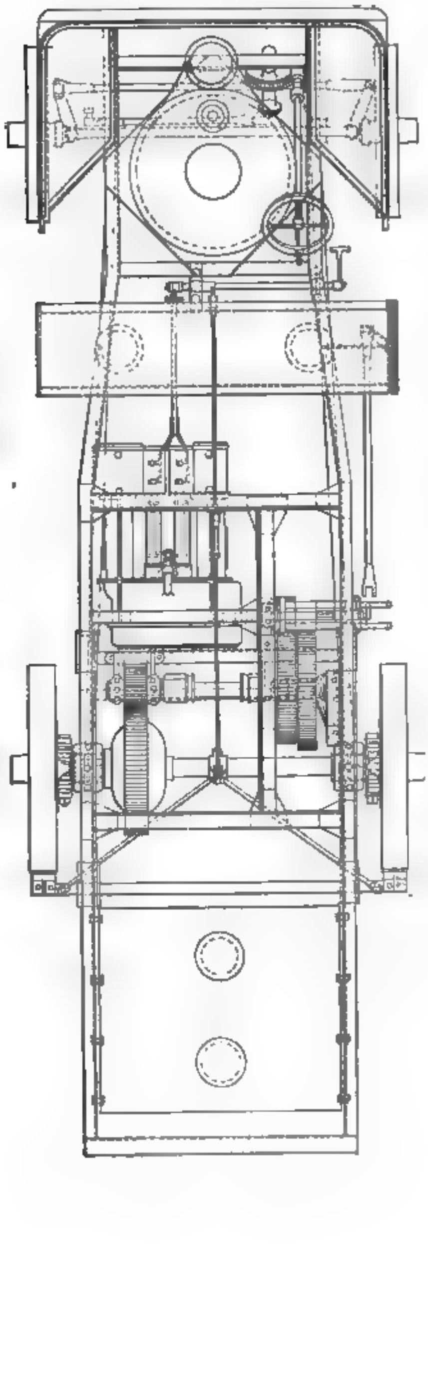


FIG. 32.—Engine and Spur-drive Connections of the Stanley Steam Carriage. The engine is "direct-connected," driving the differential through a spur gear. A vertical strut suspends the engine from the body of the carriage.

**Spur Gear Transmissions.**—Transmission of power by spur gears is in very many respects the best method of all. The drive between spurs is steadier, and is attended by smaller loss of power than between bevels. It is impracticable, however, in connection with designs including a main shaft set in the length of the frame, bevels being necessary to change the direction of motion from longitudinal to transverse rotating shafts.

Although with well-designed spurs over 90 per cent. of the delivered power of the engine may be actually transmitted to the driven shaft, the spur drive will admit of practically no interruption of full engagement between the teeth by thrusts or vibra-



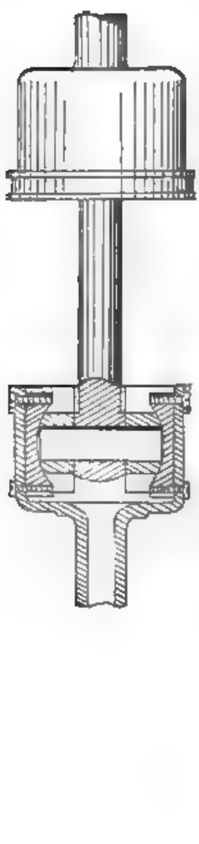


FIG. 33.—Plan of Body and Underframe of Thornycroft Long Frame Lorry, showing method of driving through spurs, change-gear and flexible jointed countershaft by spurs to the rear axle. This arrangement allows the engine to be hung above the springs and to drive to the differential below the springs, without interruption of power effort.

FIG. 33A.—Universal Jointed Counter-shaft of the Thornycroft Steam Wagon. This compensating device differs from the De Dion, which is on the axle. The object is the same, to permit of an uninterrupted drive under rise and fall of springs.

tion. Virtually the entire efficiency of the combination depends on maintaining the engagement at the pitch line. If spurs are to be used on automobiles, therefore, it follows that the driven shaft must be above the springs, or the driving shaft below them. The latter alternative is realized in electric vehicles, but the former depends upon some such arrangement of jointed axles or shafts as are embodied on the De Dion or Thornycroft wagons. The famous De Dion rear axle has the section of the shaft carrying the differential hung above the springs, and connected to the road wheels by universal slip-joints, as shown in the figure. The Thornycroft wagon has a similar slip-joint arrangement on a counter-shaft, arranged to afford a steady drive from the engine above the springs to the driving spur in mesh

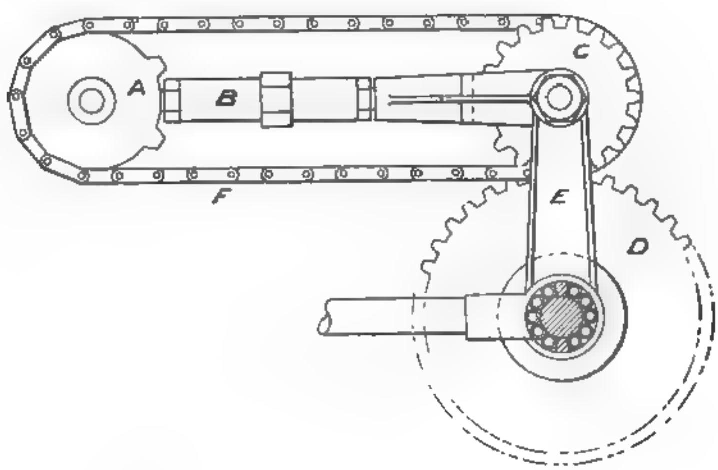



FIG. 34.—The Haynes-Apperson Spur-gear Transmission.

with the driven spur on the axle sleeve. Such devices are essential, in order to maintain a steady drive between the meshing spurs in spite of the rise and fall of the springs.

**Haynes Spur Transmission.**—A device formerly used on Haynes carriages accomplishes the end of an uninterrupted spur drive with nearly the same efficiency as the Thornycroft. As

shown in the figure, A is the sprocket fixed at one end of the counter-shaft; B, a turnbuckle on the adjustable distance rod between the first counter-shaft and the second counter-shaft carrying the pinion, C; C, a spur pinion keyed to the second counter-shaft, carrying a sprocket driven by a chain from A; D, a spur gear on the rear axle meshing with spur pinion, C, on the second counter-shaft; E, a rigid distance rod for maintaining fixed relations between the spurs, C and D. The advantages of this system are the maintaining of a steady drive without the usual wear and tear on the moving parts consequent on sprocket connections direct from the first counter-shaft, or from the main shaft of the motor. The movements of the distance rod, also, throws no strain upon the springs, as in many other forms of transmission.

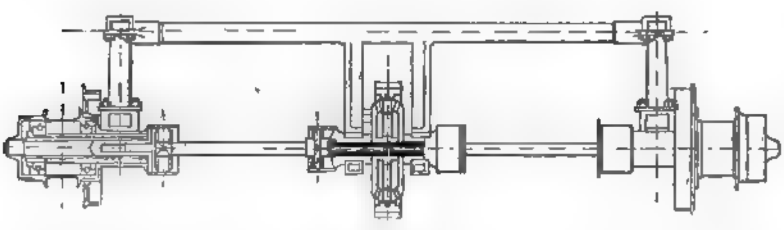


FIG. 35.—Jointed Rear-Axle of the De Dion & Bouton Carriages. By the use of universal joints between the driving spur and wheel spindles a steady drive may be maintained between the spur, hung on the body, above the springs, and the wheels, below the springs, even on the roughest roads, when the springs are constantly in action.

# CHAPTER FIVE.

## THE STEERING OF A MOTOR VEHICLE.

**Steering Gear of Automobiles.**—In a horse-drawn vehicle the front axle shaft is centre-pivoted below the body of the carriage and in turning bears on the "fifth wheel." Such an arrangement is the most practical for this class of vehicle, since the tractive power, the horse, can pull in any direction without the use of further appliances than the guiding lines or reins. In motor vehicles, since the motive power is applied to the rear wheels, literally pushing the structure from behind, it is necessary to provide mechanical means for shifting the direction of the forward or steering wheels. The forward axle shaft is rigidly secured across the body of the vehicle, and has no movement whatever. At each end it carries a fork, or yoke, to which is bolted generally at right angles to the axle shaft, so as to form a true knuckle-joint, a boss carrying two branches, one of them conical shape, to fit the axle box of the wheel, which is suitably secured, as in horse-drawn vehicles, so as to rotate freely; the other being an arm, shaped for attaching the transverse steering link bar. This link bar is generally arranged to connect the steering arms of both stud axles on the through axle shaft, the connections for the control handle or wheel, placed conveniently to the driver's hand, varying with different designers.

Pivoted axles, commonly known as Ackerman axles, furnish the readiest and simplest means for steering motor vehicles, at the same time permitting maintenance of stability. The transverse steering link bar attached to an arm at either end is readily manipulated by the driver, and with but small exertion, since the pivots, attached direct to the axles of the wheels, permit a wide angle of variation in the vehicle's direction of travel for a very slight shifting of the steering wheel or handle. The balance of leverage being also in the driver's favor, it is possible to turn the vehicle in any desired direction quickly and with ease.

**The Theory of Steering Axles.**—The best effect of pivoted steering axles depends upon fixing the steering pivot as near as possible to the centre of the road wheel, in order to enable the greatest arc of operation for the smallest motion of the hand. In this respect the steer wheel of a bicycle is typical, and some light automobiles having the wheels similarly mounted on forks have been notable for easy and efficient operation. But, since this construction is not suitable for heavy carriages, designers have busied themselves devising other methods for accomplishing the same result.

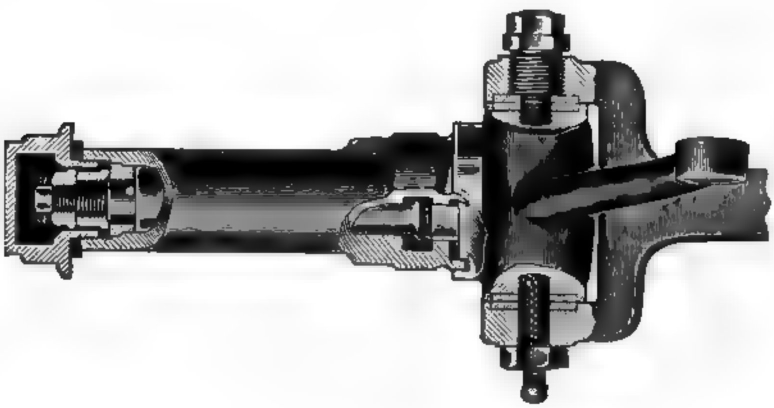


Fig. 36.—A Type of Stud Steering Axle, showing steering arm and pivot and plain bearing axle and box.

1. One of these is to incline the stud axle downward at such an angle as will cause the tire, or periphery, of the wheel to strike the ground at a point coincident with a line drawn through the knuckle pivot. As an additional advantage for this construction, it is claimed that the force of a collision is delivered at or about this line of incidence, rather than on the hub or its axle connection, thus ensuring greater security, and saving the driver a shock.

2. Another device is to incline the pivot axis inward, leaving the axle horizontal, or nearly so, with the result that, as in the

previous case, a line drawn through the pivot strikes the ground at the same point with the periphery of the wheel which is itself in a vertical position.

3. Some such arrangements as the Haynes double yoke pivot may be used with good effect. In this device one yoke is of a piece with the through axle shaft, the other pivot-bolted at each extremity within the first, and carrying the axle spindle at its centre. By this means the centre of the steering pivot may be brought to the theoretically correct position with a much smaller rake of the road wheel than is involved in the first device mentioned.

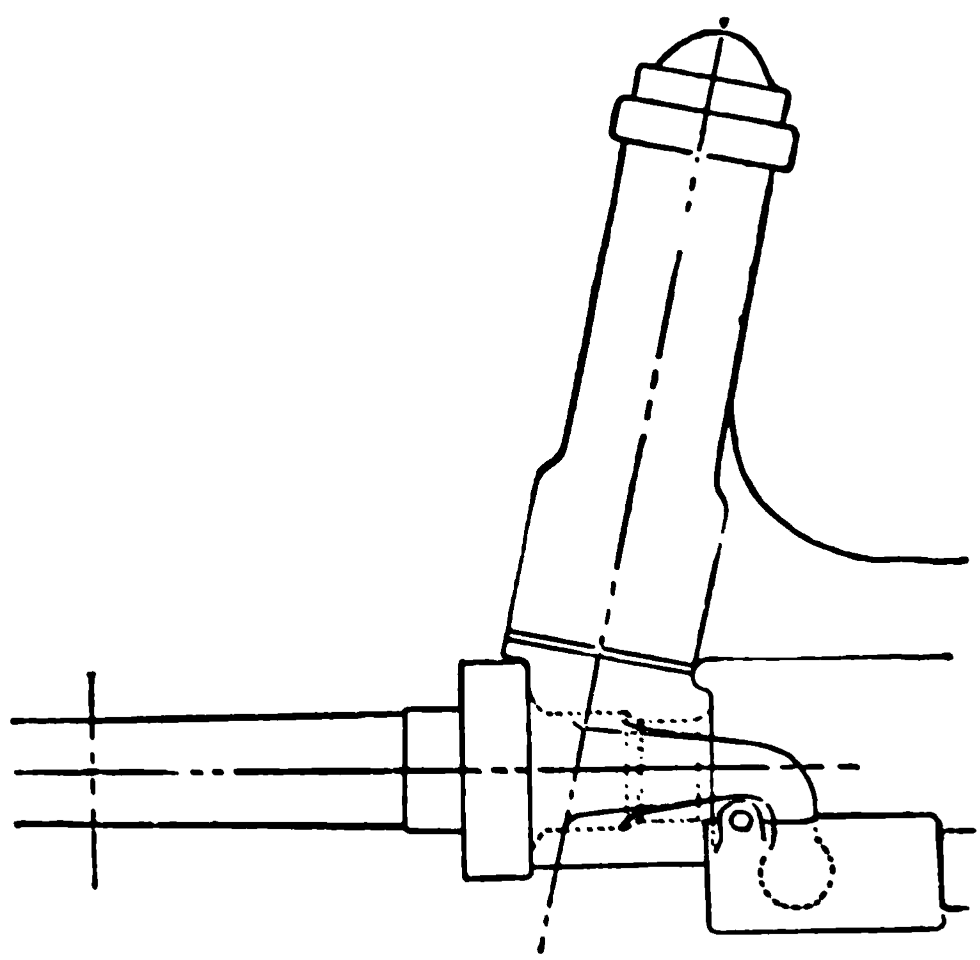


FIG. 37.—Duryea's Inwardly Inclined Steering Pivot. The lines passing through the pivot and across the axle converge to the point of contact of the tire with the ground, thus securing the effect of centre steering.

4. Several attempts have been made to place the steering pivot precisely at the theoretically correct point by use of a hollow steering hub enclosing the pivot. Of these the Riker hub is the best known. In its construction a hollow steel cylinder is penetrated by the end of the transverse axle-tree and pivot bolted to it, so as to be turned in either direction by the steering arm, *H*, fixed at its inner end. Over this cylinder the wheel hub, also hollow, is slid and turns upon it on two trains of ball bearings,

The Clubbe and Southey Hub, **Fig. 40,** operates on a simpler plan. The fork, or yoke, on the through axle shaft is slightly bent forward at the end, so that a pivot bolt through the eyes pierces a boss attached tangent-wise to a short tubular axle bearing, in which the stud axle, carrying the wheel, revolves freely. The hub is hollow and hemispherical, so as to contain the whole mechanism of the pivot joint, which is slightly forward of the centre, giving a caster action to the wheel in turning. The advantage presumably attained in this caster action is a freer and easier shifting of direction with a given effort at the steering wheel or lever.

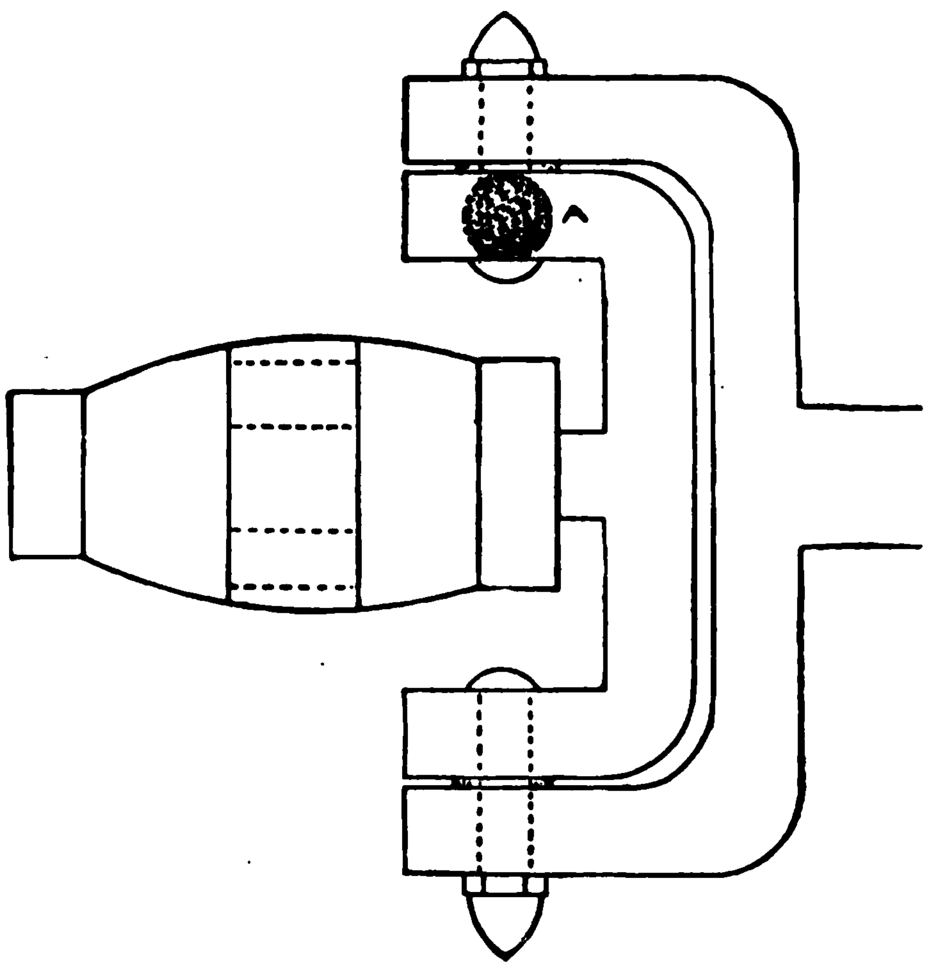



Fig. 38.—The Haynes-Apperson Double Yoke Steering Pivot Axle. The steering arm is attached at A, thus securing the turning effect at approximately the centre of the wheel hub.

**The Arc of Steering.**—To achieve the end of positive and reliable steering effect, it is necessary that the steer wheels describe concentric arcs in making a turn, with their axle bosses on radii from a common centre, differing in length as the width of the vehicle. This involves that each stud axle inclines from the straight-ahead travel line at an angle different from that of the other. The arcs described by the wheels in turning must be concentric, in order to insure continued travel in the desired direction, without side-slip or harmful resistance, such as must other-

wise result. The two wheels, having the same diameter, no matter how much their relative speeds may differ, will by any other arrangement fail to run in the same curved direction.

**Turning Arc in Railroad Wheels.**—The same principle is applied in railroad cars and locomotives in a manner impracticable with motor carriages. Here, although the wheels are always rigidly attached in pairs at either extremity of rotating through axles, and in fours to the trucks, composed of two parallel through rotating axles with their attached wheels, the differing concentric arcs described by the two rails of the track in round-

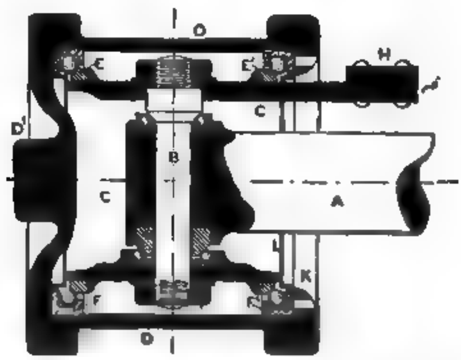



FIG. 39.—Riker's Pivoted Steering Hub. A is the axle shaft; B, the pivot connecting A to the tubular swinging hub, C. E and E' are annular cones which bear on the balls mounted in the ball races, F and F', thus permitting the hub D to rotate independently on the inner tube, C. The steering arm, H, attached to C turns both C and D on the pivot, B.

ing a curve are followed. To accomplish the desired end, railroad car wheels are made with a cone-shaped tread—a double cone, in fact—the base being against the flange of the wheel. In turning a curve, then, the outer wheel, impelled by centrifugal force, rotates on its largest diameter, while the inner wheel, from the same cause, rotates on its smallest. The effect approximated is that of an elongated cone whose point is at the centre of the arc of turning, and its base on the periphery. Thus is approximated the theoretical requirement that the two wheels on an axle should be of different diameters in making a curve. Since, however, the diameters of motor carriage wheels may not be varied by this or

any other means, it is obvious that the only other available device is such a variation of the steering angles as has already been mentioned.

**The Steering Wheels.**—When a carriage's travel is changed from the straight-ahead direction to a curve, the steering wheel moving on the in-track, or smaller arc, must assume a greater angle at the axle than the outer wheel, which moves on the larger of the two concentric arcs. It is evident, moreover, that such variation of axial angles must be accomplished by some device at

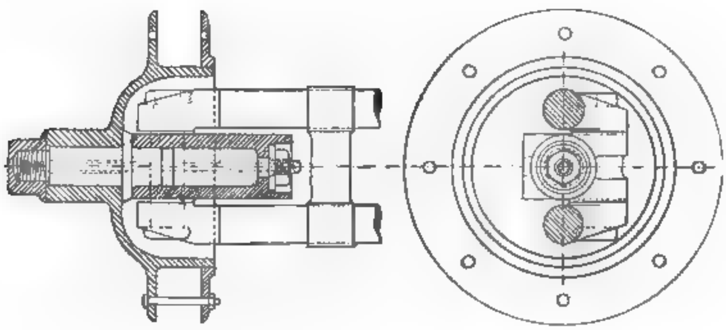


FIG. 40.—The Clubbe and Southey Pivoted Steering Hub. As may be seen, the pivot is to one side of the axle, thus giving the wheel a true caster movement in turning. See Page 45.

the steering arms of the stud axles. If these steering arms be fixed at right angles to the axles, so that the transverse drag-link is of a length theoretically identical with the distance between the wheel treads, any effort to turn the wheels in steering will shift the angles of both arms with the fixed axle-tree equally, hence, causing the axles to assume positions as radii from different centres. The result will be that the outer wheel will describe an arc tending to cross those described by all the other wheels, and may slide or rub, without revolving, as much as one foot in every six. Such a procedure must, of course, retard the progress of the vehicle very seriously, and, from the uncertainty of steering involved, must be particularly troublesome, even dangerous, on narrow turns. It is evident in this case that the outer wheel axle is at too great an angle, or that the inner is at too small an angle.

**Steering Constructions.**—The simplest method of at once obviating this trouble and also securing the proper angles of the axles is to incline the two steering arms inward from the right angle and make the transverse drag-link shorter than the distance between the axle pivots. If the drag-link be in front of the axletree, the steering arms are inclined outward, making the drag-link longer than the distance between axle pivots.

With this arrangement, as may be readily understood, any effort to change the direction of the travel will cause the arm of the outer wheel to approach the right angle with the transverse through axle bar, and cause the arm of the inner wheel to move proportionately away from the right angle. Moreover, since the

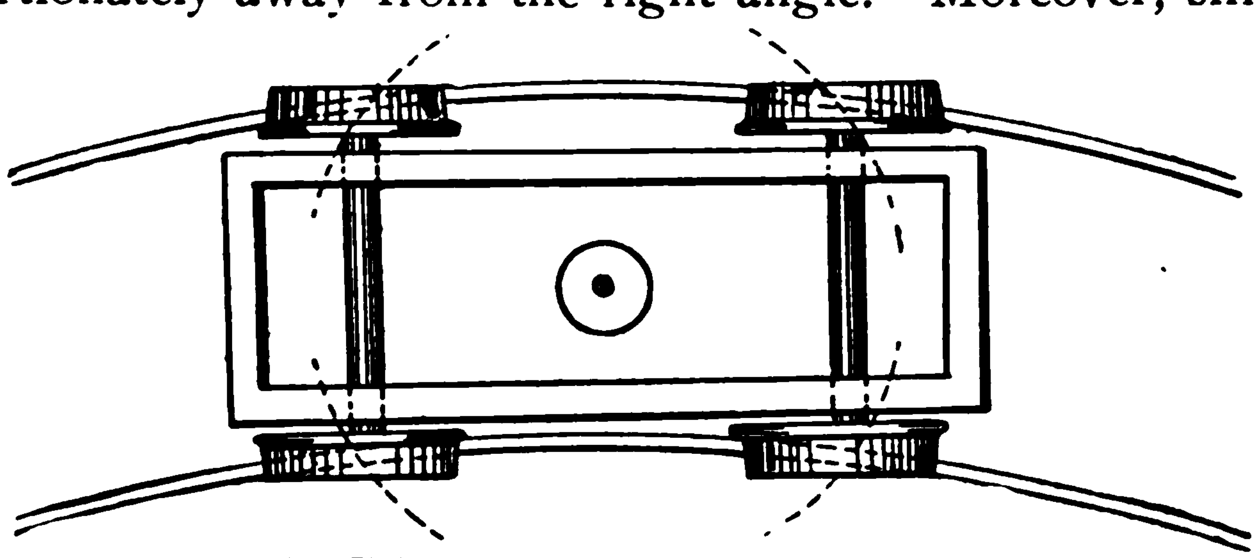


FIG. 41.—Position of the Wheels of a Railroad Car on the Rails in Turning a Curve, showing how the outer and inner wheels turn on different diameters, thus compensating the parallel arcs of travel.

end of the transverse drag-link attached to this inner axle-arm must, in the act of thus widening the angle, be approached nearer and nearer to the immovable through axle bar, it must describe an arc, thus passing through a greater number of degrees than will the opposite or outer end. Consequently, the object of securing a greater angular inclination for the axle of the inner wheel will be accomplished and the proper difference for all usual conditions between the angles of the two approximated. That is, although it generally happens that the angular inclination of the steering arms works best on curves of radius midway between the extremely long and extremely short, it has been found that the difference is not sufficiently great to disturb the parallelism of the described arcs or cause damaging slips or skidding of the rear wheels.

**The Steering Angle.**—Generally, the steering angle of a motor carriage, which is to say the sum of the inclinations of the two steering arms from the right angle, is between fifty and sixty degrees, giving an inclination for each arm of between twenty-five and thirty degrees. Some of the best makes of carriage have it at or about twenty-five degrees for each arm. As shown in the

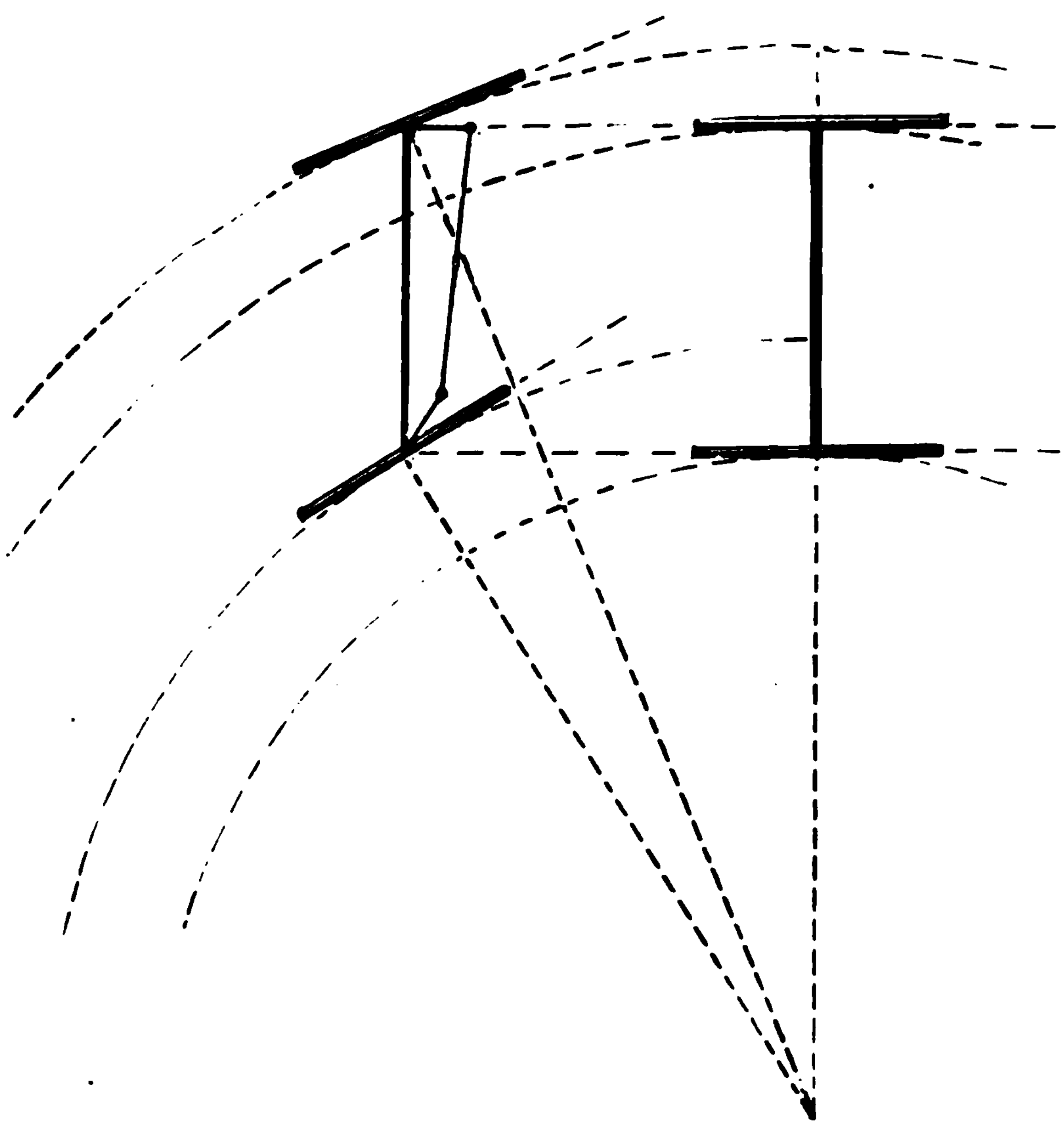


FIG. 42.—Diagram illustrating the Position of the Steering Wheels of a Motor Carriage in Turning. As will be seen, they both are tangential to arcs described on a common centre, as is necessary in order to describe such concentric arcs and give positive steering, when the motive impulse is from behind.

accompanying diagrams, however, various designers have modified the typical arrangement of inclining the steering arms inward and using a drag-link to connect them by such devices as:

1. Placing the arms at right angles and using a link in two sections connected to a fork or bell crank having the total required angle, fifty or sixty degrees, and pivoted at the centre of the fixed axle bar.

2. By dividing the angle betwen the centre-pivoted bell crank and the steering arms, making the former, say thirty degrees and the two latter fifteen degrees each.

The primary object achieved in either of these devices is to ensure the end of ready manipulation of the steering lever. The first-named construction is the one best suited to carriages having the steering pivot in the theoretically correct place—within

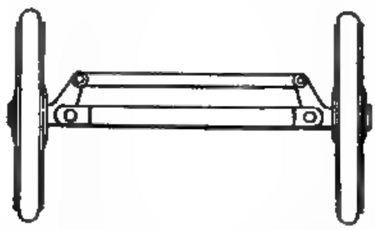


Fig. 43.

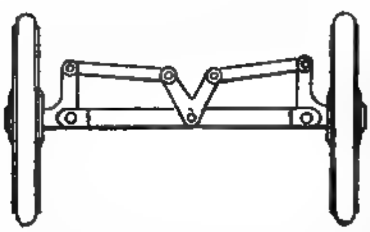


Fig. 44.

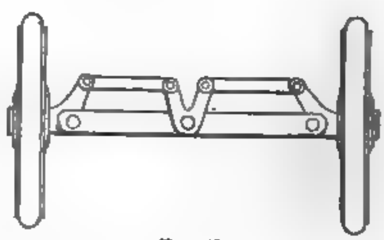


Fig. 45.

Figs. 43, 44 and 45.—Diagrams of Motor Carriage Forward Axles, showing three arrangements of link bars and steering arms. In the first the steering arms are inclined inward at the required angle and connected across the carriage width by a single link. In the second the steering arms are fixed at right angles to the axle-tree, and the angle of inclination is made at a centre pivoted bell crank. In the third the angle of inclination is divided between the steering arms and the central bell crank. Theoretically, the sum of the angles in the third figure is equal to that in the first, and to the angle of the bell crank in the second.

the hub. When for structural reasons the transverse drag-link bar is placed in front of the axle-tree, a position preferred by several manufacturers, the steering arms attached to the bosses of the swinging axles are inclined outward, instead of inward, at the angles found most suitable with reference to the width of the vehicle between the wheel pivots and to the diameter of the wheels.

The construction adopted by some designers of inclining the axle stud inward, as already described, achieves, not only the very desirable end of centre-steering, but also allows a certain inclination, or rake to the steering wheels, as in a bicycle, when making a turn. The rake is a positive advantage to ready steering qualities, when the inclination of the axle pivot is not at so great an angle as to bring unusual side strain on the wheels. Other things being equally favorable, it is also efficient in reducing the steering effort.

**The Center of Gravity and the Wheel-base.**—There are several questions intimately associated with the problem of correct steering angles. Among these are considerations on the most reliable means for avoiding skidding or side-slip of both rear and front wheels, and on constructions best adapted to maintain balance of the vehicle in making short turns. The progress of motor carriage design in recent years has established the principle that a low center of gravity is a necessity in high-speed cars, in order to avoid the tendency to overturn at a sharp inclination of the steering wheels. The adjustment of the center of gravity has resulted progressively in two tendencies, now prevalent—the long wheel-base and the short clearance between the bottom of the car and the ground. Both conduce to comfortable riding and immunity from overturning. Side-slipping is also avoided in large measure. With very long cars, however, difficulty is experienced in turning sharp corners, or in steering on any but easy curves, except with a very narrow front. These matters will be explained in place.

**Skidding.**—The term, "skidding," or side-slipping, as generally applied in motor car practice, describes the occasional tendency of the rear wheels to slide sideways to the direction of travel. The result may be disastrous, as well as annoying, since, in the event of colliding with a large or immovable obstacle the wheel may be broken in pieces, or, unless the center of gravity is low, the vehicle will be overturned. The same term is also applied to a similar behavior in the front wheels.

According to authorities, the immediate occasion of side-slip is found in the fact that under certain conditions a wheel revolves more rapidly than it progresses, or progresses more rapidly than it revolves. In either case it slides over the road surface, which does not present sufficient adhesion to promote traction,

FIG. 46.—Anti-skidding device on the rear wheel of a Mercedes limousine. A network of steel chain offers sufficient resistance to prevent side-slip and skidding on a greasy street.

or the balance of rotation and progression. Particularly when the tread of the tire is flattened at contact with the ground, as usually happens with pneumatics, the loss of adhesion results in such a resolution of the propelling power or momentum of the vehicle as will allow of motion in lateral directions, as well as straight ahead.

Skidding occurs under several conditions:

1. When the brake is suddenly thrown in.
2. When the clutch is suddenly thrown in or out.
3. When the steering gear is given a sudden or sharp inclination.

As may be readily understood, either of the former events tend to interrupt the balance of progress and rotation—hence cause skidding. However, the most familiar cause is found in the third instance. Any inclination of the steering wheels produces a side pressure on all the wheels, but a large turn is particularly liable to result in side-slip, from the fact that the propelling power and momentum continue to urge the vehicle forward, leaving a large part of the active energy unresolved into movement on the arc of turning. In such a case, also, as may be readily understood, either rotation or progression is the greater; thus adhesion between the wheel and the roadway is lost.

**Protection Against Skidding.**—Any device that will promote traction will prevent skidding. We find, therefore, that the most effective apparatus to this end are those that enable the tire, as it were, to bite into the road surface, rendering difficult sliding or slipping in any direction. Such are net-works of rope or chain, hob-nailed tire covers, and conical projections molded into the rubber of the tread. In addition to such surface precautions, there are important considerations in the design and balance of the vehicle structure. The proper location of the center of gravity is now recognized as of extreme importance, and, particularly in very long vehicles, also, the width of the steering apparatus. In former times, when designers were still discussing the proper position for the heaviest weights on the frame, an overloaded forward axle frequently left the rear wheels so lightly burdened as to allow the vehicle to turn end for end on a greasy asphalt street, or a slight inclination of the steering wheels. At present such a catastrophe should be impossible from this cause, on account of better distribution of the load and the use of long wheel-bases.

**Duryea's Explanation.**—Charles E. Duryea, a prominent American automobile authority, gives the following explanation of the matter:

"In some cases skidding is caused by unequal forces at the rear wheels. For example, if a brake is applied on one the other continues to force the vehicle forward and the vehicle tends to move around the slowest wheel. This may cause skidding of the front end, or it may start skidding at the rear end. If, for any reason, more power is applied to one rear wheel than to the other, the same result follows. If the brakes are suddenly applied while the vehicle is being turned, the wheels may start sliding and, once started, they slide sidewise as readily as any other direction, so that a little deviation in direction of the steering wheels may cause the vehicle to skid. It is readily seen that a change of direction brings the front wheels out of a position straight ahead and causes the rear end to swing sidewise just as an increased resistance on one front wheel would do. Longer wheel base lessens skidding by decreasing the angle between the lines through the centre, and to one of the forward wheels. The gain by increasing the length of the wheel base is not nearly so pronounced as that by narrowing the tread of the front wheels, and this construction is undoubtedly preferable. While rear wheels should be constructed to track with ordinary carriages, front wheels under most conditions should not, for if they track they are liable to refuse to come out of wet car tracks, are almost impossible to get out of deep ruts, and are therefore not so safe as where one or both, because of difference in tread, are kept out of the tracks or ruts. The only objection to front wheels not tracking is in sandy roads, where the depth of the rut will cause one front wheel or the other to skid into the rut, and thus swing the vehicle diagonally across the road in its attempt to move forward."

**Analysis of the Diagram.**—Mr. Duryea explains his contentions by the accompanying diagram:

"Suppose *aa* to represent the front wheels of a motor vehicle, *bb*, the rear wheels and *c* the centre of gravity. If either front wheel, *a* meets an obstacle throwing an increased resistance to motion on that wheel the mass of the vehicle, acting on the centre of gravity, *c*, together with the driving power on the rear wheels which, in effect, are pushing *c* straight forward, will tend to revolve the entire vehicle; that is to say, the centre of gravity *c* around *a*, because of the fact that a line through the centre of gravity *c* in the direction of motion passes considerably to the side of *a*, which gives rise to the attempt to revolve around *a*. Suppose, for argument, the front wheels to be placed at *dd*, it will readily be seen that any increased resistance on one front wheel tends to

stop that corner of the vehicle, and both the inertia of the vehicle, and the push on the rear wheels, carry it forward and sidewise; or, in other words, cause it to skid. This effect is plain with the exaggerated position of the front wheels *dd,* and the same effect although less, exists with the front wheels *aa.* If, however, these wheels are brought close together, the closer the better, or if a single front wheel, *e,* is used, the tendency to skid is very much reduced. In this case a resistance against the front wheel is met directly by both the push of the driving wheels and the inertia of the vehicle and no tendency to skid results.

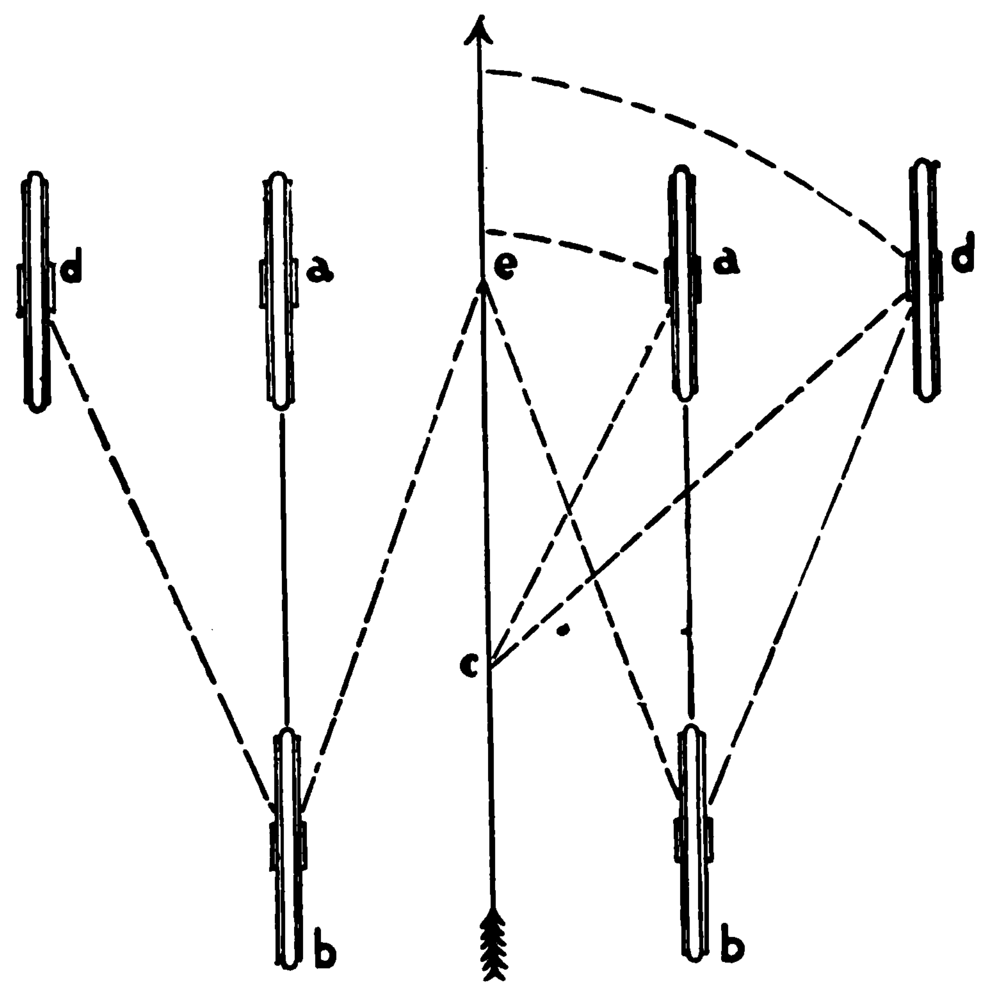



FIG. 47.—Diagram illustrating Duryea's explanation of the influence of the wheel-base on steering and side-slipping.

"Sometimes instead of the hind wheels, it is the front ones that skid, but the same causes act to produce this. For example, if the rear wheels, *bb,* refuse to slide, the increased resistance, such as snow, mud or sand on one front wheel, *d,* will tend to swing that corner of the vehicle sidewise out of its path, taking the other wheel, *d,* with it. This form of skidding is particularly found on roads that slope to one side, where one outer wheel gets in the gutter and slews the front end of the vehicle around. It is no less dangerous than the other, although less seldom found. The exaggerated diagram makes the effect plainly apparent and narrowing the wheels betters the results until they are brought together at a common centre.

"The farther to the rear the centre of gravity, *c,* is located, the less the angles and the greater the immunity from skidding."

**The Long Wheel-Base and Steering.**—Within the past few years the safety and comfort of passengers has been increasingly identified with the long wheel-base, which secures the desirable ends of a low center of gravity, steadier running and reduced danger of skidding, and is variously alleged to embody advantages in easier steering. That the latter claim holds good on long turns may possibly be true; that it is not the case on short ones is readily discovered. The following explanation from a popular authority serves very well to explain this point:

"When intricate manœuvring is required, and on rough roads generally, too long a wheelbase proves objectionable. In the first place it is found that a given angle of the wheels will not produce as great a change in

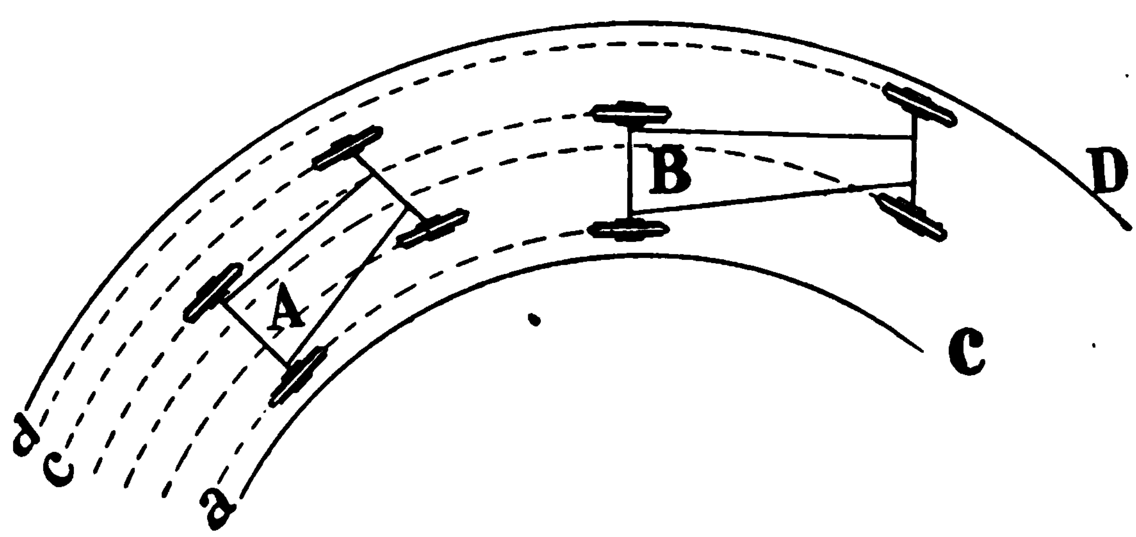



FIG. 48.—Diagram illustrating the effect of a relatively long wheel-base on the turning arc of a motor carriage.

direction when the wheelbase is long as when it is short. This means harder steering, and closer attention on the part of the driver, since very sharp turns cannot be made, and must be avoided by long sweeps, commencing earlier than would be necessary with a short wheelbase. When going very fast, the difficulty is much magnified and great watchfulness is necessary to steer a desired course.

"In going around a curve with a motor car, it will be noticed that the rear wheels do not follow in the tracks of the front wheels, but swing considerably closer to the inside of the curve. The longer the wheelbase, the greater this sidewise displacement of the rear portion of the vehicle, and the wider the space occupied by the car while making the turn. Therefore, with a very long wheelbase, a narrow road in many cases may be barely wide enough for all the wheels of the car when a short turn is made on it, and passing another vehicle may be decidedly dangerous, if not absolutely impossible. * * * * * *

"Perhaps the easiest way in which the lay reader can make the foregoing comparisons between long wheelbases and short wheelbases clear in his mind is to assume the cases of a very short and of an impossibly long wheelbase.

Thus, with a wheelbase only a foot or two long, it is evident that the steering would be very sharp upon the least movement of the front wheels, and that the rear wheels would follow almost in the track of them. On the other hand, with a wheelbase one hundred feet long, it clearly would be impossible to go around a curve on an average road, and a great angle of the steering wheels would be necessary to produce a turn even of wide radius. Of course, these are exaggerated examples, but they serve to suggest an idea that applies very definitely, though in lesser degree, to wheelbases ordinarily long. It is true that modern cars with long wheelbases usually have frames much narrower in the front, to permit of turning the steering wheels at very sharp angles, but this is a means of getting around rather than of doing away with the difficulty."

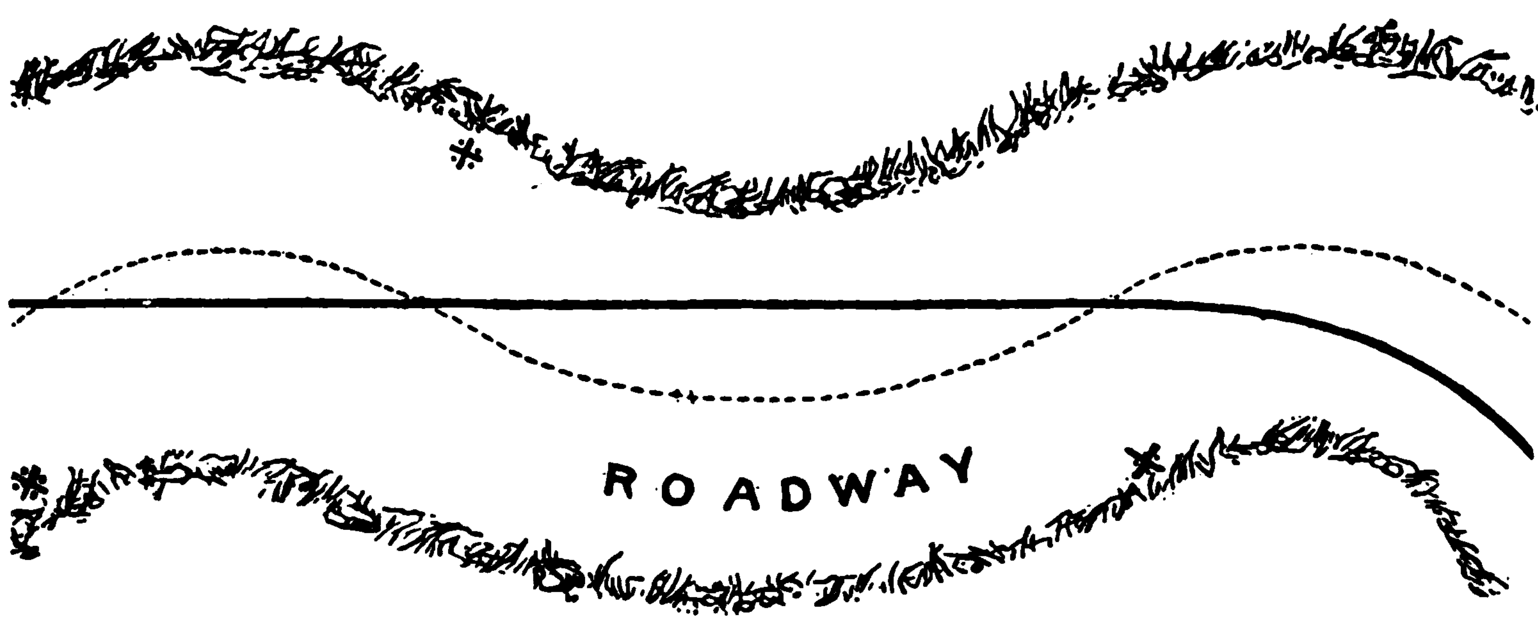



FIG. 49.—Diagram illustrating a straight course avoiding sharp turns and side-slips at points marked by crosses (x x x). Dotted line, course to avoid; straight line, best course to follow.

**Avoiding Side-Slip in Driving.**—The accompanying diagram, borrowed from the "Motorist's Year Book," exhibits a notable condition in which side-slip may be readily incurred and avoided. The explanation of the diagram is as follows:

"At each of the points marked in the diagram by crosses, if the road is greasy and the curves abrupt, the motorist will stand a chance of side-slip. His straight road, giving no opportunity of lateral pressure on his wheels, will diminish his side-slip risks to one, the last curve wherein the road is shown turning off at a sharp angle. This he must take, of course, but he will do well to take it as broadly as possible. The saving of tires by such a method is surprising, every sharp twist and turn acting de-

structively, according to its angle of abruptness. It is, of course, supposed that the driver can choose his route, the road being unfrequented, and a fair outlook obtainable, conditions to be found over miles and miles of country driving. Where there is traffic, the rule of the road must be more or less strictly observed; as also in turning corners, beyond which one cannot see.

"In climbing hills, again the automobilist should preserve the straightest possible course. A horsed vehicle zig-zags, in order to spare the horse, by making the wheels act laterally, and so act as brakes to prevent the backward slipping tendency of the vehicle. In driving a car the practice is different. If the course is altered the front wheels exert a lateral pushing action on the road surface and retard the car. As power is valuable upon hills, it should never be wasted in turns, abrupt or gentle, if these can be avoided."

**Wheel and Tiller Steering.**—The steering gear of a motor carriage is controlled by a tiller or hand wheel at the driver's hand. The difference between the two is very largely a matter of design, except in the heavier types of car; since, after all, the wheel is a multiple lever. In practice, although the balance of leverage is evidently on the side of the driver, even with the simplest form of steering device, the advantages of the wheel are manifold. With the best-designed apparatus to neutralize vibration and prevent any outside stress from reversing the steering, by acting to change the direction of the road wheels, the tiller may be whipped out of the driver's hand. It is also tiring to hold it, even in the straight-ahead position, while, on making a turn, a large arc must often be described. With a wheel the hands may always rest in an easy and natural position, and no ordinary shock can loosen the hold. The driver always has the control in hand.

**Irreversible Steering.**—In early motor carriages the steering tiller or wheel was connected direct to the axle studs by arrangements closely resembling the simple steering control of a bicycle. The result was, of course, an immense expenditure of strength in effecting changes of direction, not to speak of constant annoyance from jolting and vibration, and the danger that some unexpected obstacle would whip the lever from the hand. The

necessity of devising suitable means to render steering irreversible—which is to say, immune from interference by obstacles acting on the road wheels—was very early recognized. Typical methods of achieving this result are shown in accompanying diagrams. In all of these the neutralization of vibration is more or less successfully combined with irreversibility.

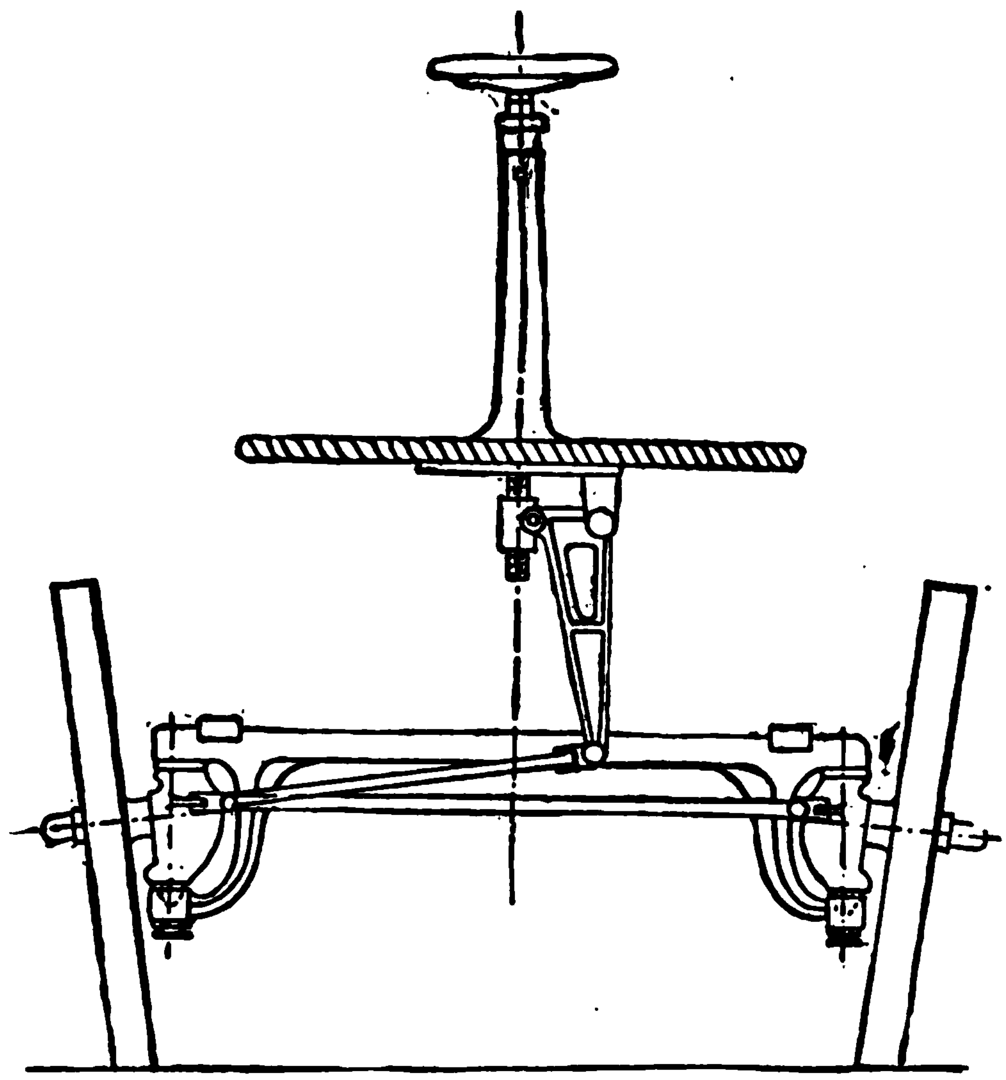


FIG. 50.—Steering Arrangement of the Clarkson-Capel Steam Wagon. The spindle of the steering wheel carries a screw at its end, which works a boss, as the wheel is turned, thus actuating the lever and drag-link attached to the arm of one of the axle pivots.

**The Traveling Nut.**—The simplest arrangement is the screw and sliding nut device, used on the Clarkson-Capel steam wagon and several others. In this device, as shown in the figure, the pillar or spindle of the steering wheel is threaded at its lower end, and upon it a nut or threaded boss is let on. This nut carries a lug for attaching one arm of a fork or bell crank, whose other arm actuates a drag-link working on the steering arm of one of the axle studs. When the steering pillar is rotated, the nut is caused to move up or down on the thread, operating the bell-crank and link and giving an inclination to the road wheels.

While, as may be plainly seen, the inclination thus imparted to the road wheels is irreversible—since the gearing connected to the sliding boss is locked in any given position—there can be no certain freedom from vibration at the hand wheels.

**The Worm and Sector.**—In the second type of steering gear the lower end of the steering pillar carries a worm that rotates a toothed sector. On the spindle of this sector is carried an arm that actuates the steering axles through a drag-link in fashion

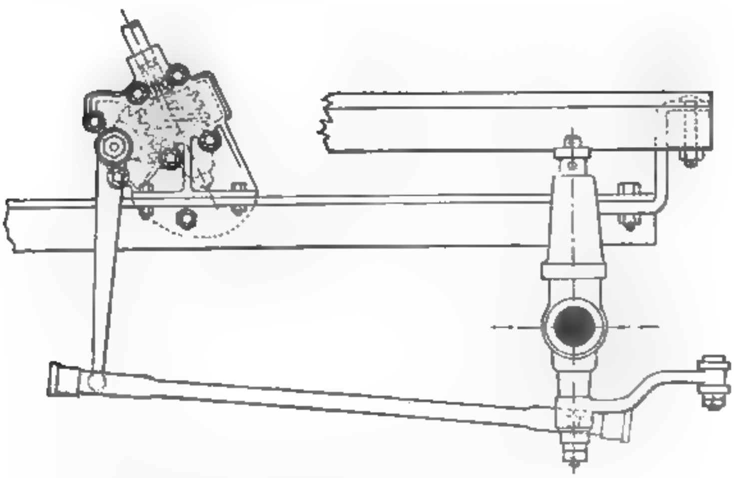
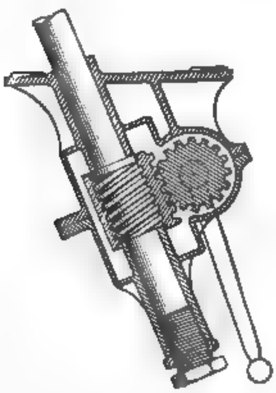


FIG. 51.—Worm and sector steering device, as developed by Panhard-Levassor. The spindle of the steering hand wheel carries a worm gear at its base, which actuates a toothed sector, as shown. This swings an arm and moves the drag-link attached to the arm at the base of the steering head. The transverse drag-link connecting the two steering heads is attached to the arm extending from the front of the carriage. The link between the steering head and the sector arm has ball joints and can adjust the distance as the carriage rises and falls on the springs.

similar to the former device. Ball joints between the drag-link and the arms at either end enable it to compensate the up-and-down motion of the springs. Since the worm can actuate the gear, while the gear cannot actuate the worm, this type of steering is also irreversible; although, as in the former case, vibration may be readily imparted.

**The Traveling Nut and Rack.**—Combinations of the two foregoing types of steering gear have been produced by several designers. In one of these the worm on the steering pillar causes a threaded boss to work up or down, as in the first type of apparatus. Instead, however, of actuating a bell-crank, it carries a rack, which, in turn, rotates a spur pinion, swinging an arm and drag-link in the manner already explained. Others have arranged the worm and threaded boss, with its rack attachment, in a horizontal position, rotating the worm shaft through bevel gears from the steering pillar. Both these arrangements are very efficient in neutralizing vibration.



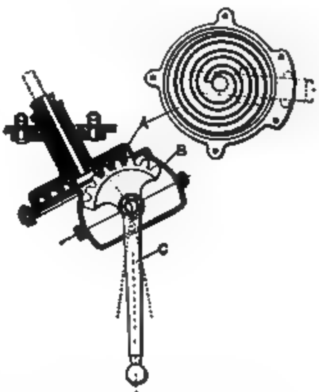



FIG. 52.—Combined Nut and Rack Steering Gear; a device embodying a high degree of immunity from back-lash and a close approximation of perfect irreversibility.

FIG. 53.—Typical Irreversible Steering Device; a spirally grooved gear plate operating a sector.

**The Gobron-Brillie Gear.**—The Gobron steering apparatus, used on the French-built motor carriage of the same name, is noteworthy as achieving the end of irreversible steering by somewhat different means. As shown in the accompanying figures, A is a hand wheel, at the end of whose spindle, D, is an arm, E, to which is pivoted a toothed sector, B. The arm, E, being moved as the wheel, A, is turned, carries around with it the pivot of the sector, B. This sector meshes with the pinion, C, turning loose on the steering pillar, as shown, and is accordingly rotated

through an arc. Thus the arm, F, attached to the pivot of B, on E, has a double motion, which involves that the slightest movement of the wheels, A, is unusually effective in actuating the steering arms, through the link attached, as indicated, to the end of

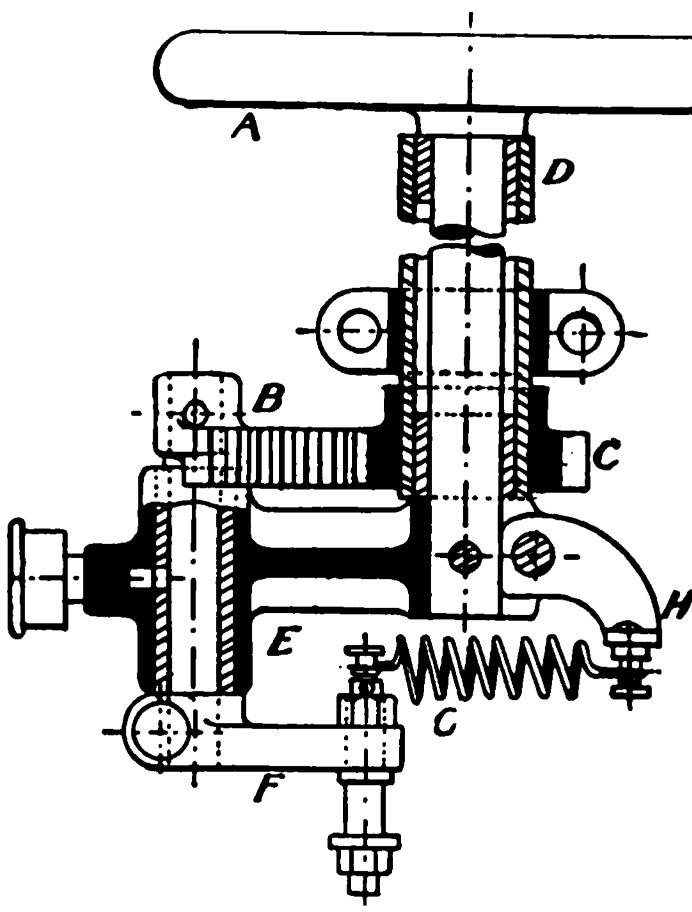



FIG. 54.

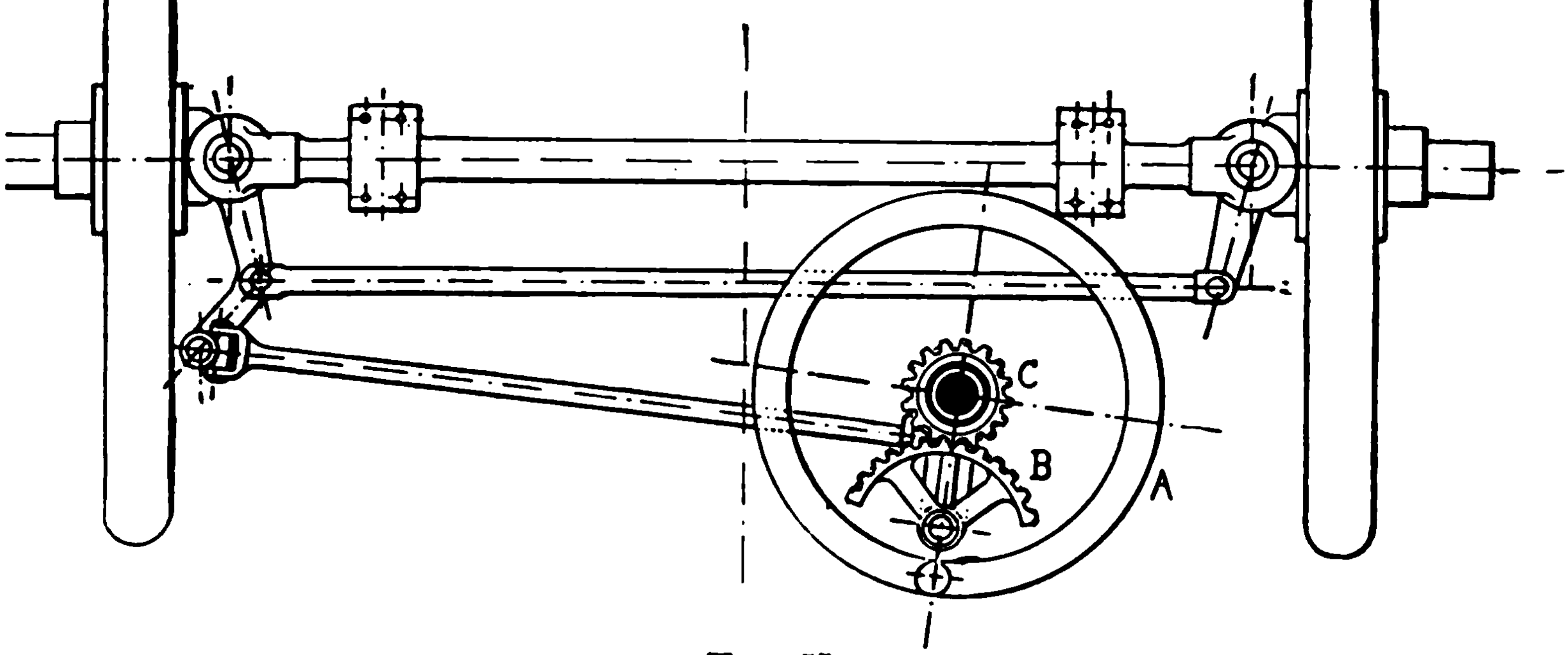



FIG. 55.

FIGS. 54 and 55.—The Steering Arrangement of the Gobron-Brillie Carriages.

F. Also, any stress at the wheels is unable to reverse or disturb the movement thus directed. The spring, G, attached to the arm, H, serves to steady the movement and restore F to normal position v ed.

## CHAPTER SIX.

### COMBINED STEERING AND DRIVING.

**Unusual Steering and Driving Devices.**—The standard, and very probably, the permanent construction for an automobile is to drive to the rear and steer on the forward wheels. However, numerous alternate constructions have been attempted at various times; some proving moderately successful, others failing outright. These may be divided into the following heads:

1. Front driving and steering: a complete failure.
2. Front driving and rear steering: a complete failure.
3. Four-wheel driving and front steering: moderately efficient.
4. Four-wheel driving and four-wheel steering: efficient but complicated.

**Front-wheel Driving.**—Front-wheel driving, as embodied in the various types of motor wheels and fore-carriages, so common some years since undoubtedly originated in a desire to adapt horse carriages to motor-driving. When embodied in the design of motor vehicles, among which were several well-known electric cabs, the construction was undoubtedly based on a misapprehension of the involved conditions of automobile operation. In both cases the error arose from an idea that horse-traction was thus imitated.

Front-wheel driving involves some kind of device for combining the steering and driving functions, unless, as has occasionally happened, the steering is on the rear wheels. Fig. 57, showing a combined driving and steering device, as used in some of the Hurtu electric cabs, shows one arrangement of gearing for accomplishing the result. Here *I* is the armature of the motor, *NN*, the magnets and *B*, a frame supporting the armature spindle which rotates on the axis, *XX*. To this spindle is attached the spur pinion, *P*, which meshes with the pinion, *r*, turning on the axis, *yy*, within the boss of the steering pivot. The spur pinion, *r*, is

made in one piece with the bevel pinion, *a*, and this latter engages the toothed bevel ring, *b*, which is clamped to the spokes of the wheel, *RR*. As may be understood, it is possible to swing the wheel, *RR*, on the axis *yy*, fixed in the yoke, *E*, without inter-

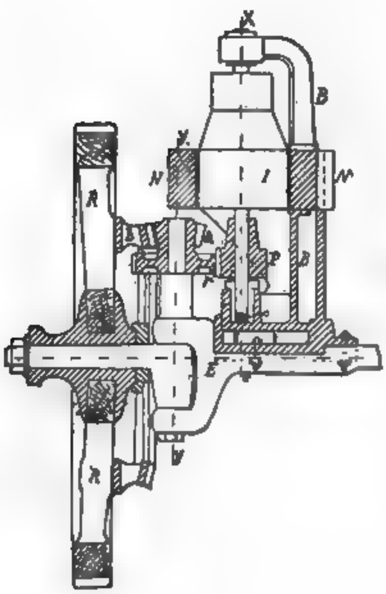


FIG. 57.

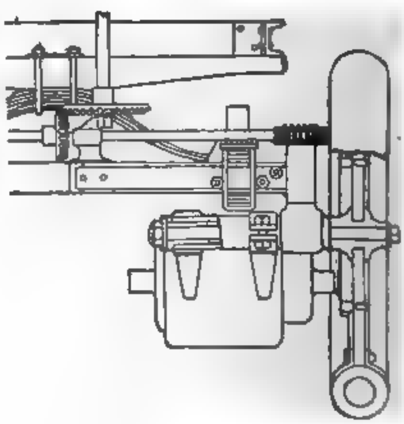


FIG. 58.

FIG. 57.—Motor Steering Wheel of the Hurtu Cabs. A drag-link attached to the arm of the pivots can turn the wheels without disturbing the operation of the motor.

FIG. 58.—Steering Motor Wheel Arrangement, by which a worm gear and pinion device, actuated as shown by bevel gears, turns the stud axle entirely around with the attached motor and gearing, without interrupting a steady drive.

fering with the transmission of driving power from the pinion, *a*, to the bevel ring, *b*, thus permitting the vehicle to be steered and driven on the same wheel. Another device, shown in Fig. 58, involves the use of a separate axle for each steering-driver.

Front-driven vehicles travel moderately well on a level roadway, but are quite useless for hill-climbing, from the fact that the centre of gravity is thrown so far back of the engine that the front wheels tend to turn without progressing. When, on the

other hand, the rear wheels drive, the centre of gravity falls forward of the axle, and good traction is possible.

**Rear-Wheel Steering.**—The objections to rear steering are that, when a carriage is standing near a curb, it is impossible to turn off sharply, as the steering wheel (rear) would run into the curb; and that, when near a ditch or impassable section of the road, in order to turn away from these, the steering wheels (rear) must first run toward them, which may lead to difficulties.

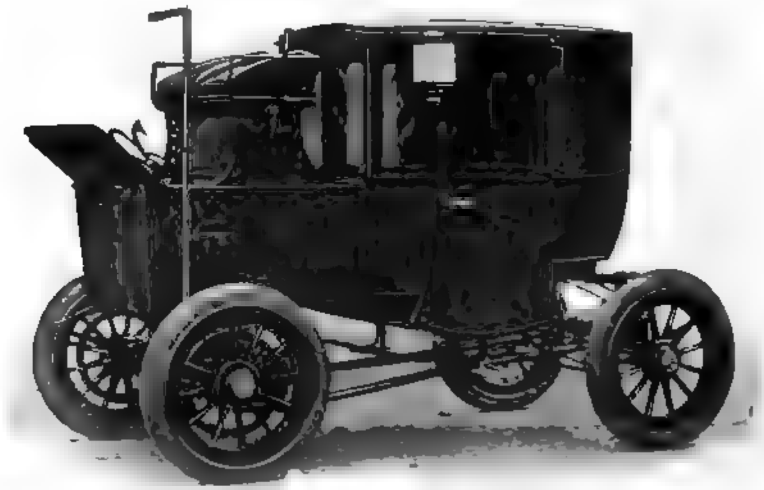


FIG. 59.—Front-Driving Brougham of the Electric Vehicle Co., used in New York City. This model, which is no longer manufactured, represents a construction very suitable for city service, but quite inappropriate for country and general use.

**Four-Wheel Driving and Steering.**—There are several advantages to be gained by driving on all four wheels.

1. Foremost among these is the fact that the driven steer wheels, being propelled by power directly applied, follow any arc in which they may be inclined. The vehicle is thus pulled around and so turned more readily than when the rear wheels are obliged to push it through a sharp curve, often at the risk of skidding, or of causing the front wheels to side-slip.

2. The driving power, being evenly distributed, propels the vehicle with better balance.

3. Four-wheel driving would probably neutralize the tendency to skid, when the steer wheels are inclined from straight-ahead travel. With four-wheel steering or an even inclination given to all the wheels at any turn, it is fairly evident that the skidding tendency would be reduced to the lowest terms.

Fig. 60 shows one of the best of the numerous proposed devices for four-wheel driving. As may be seen, the driving is by two shafts and two sleeves running in the length of the carriage,

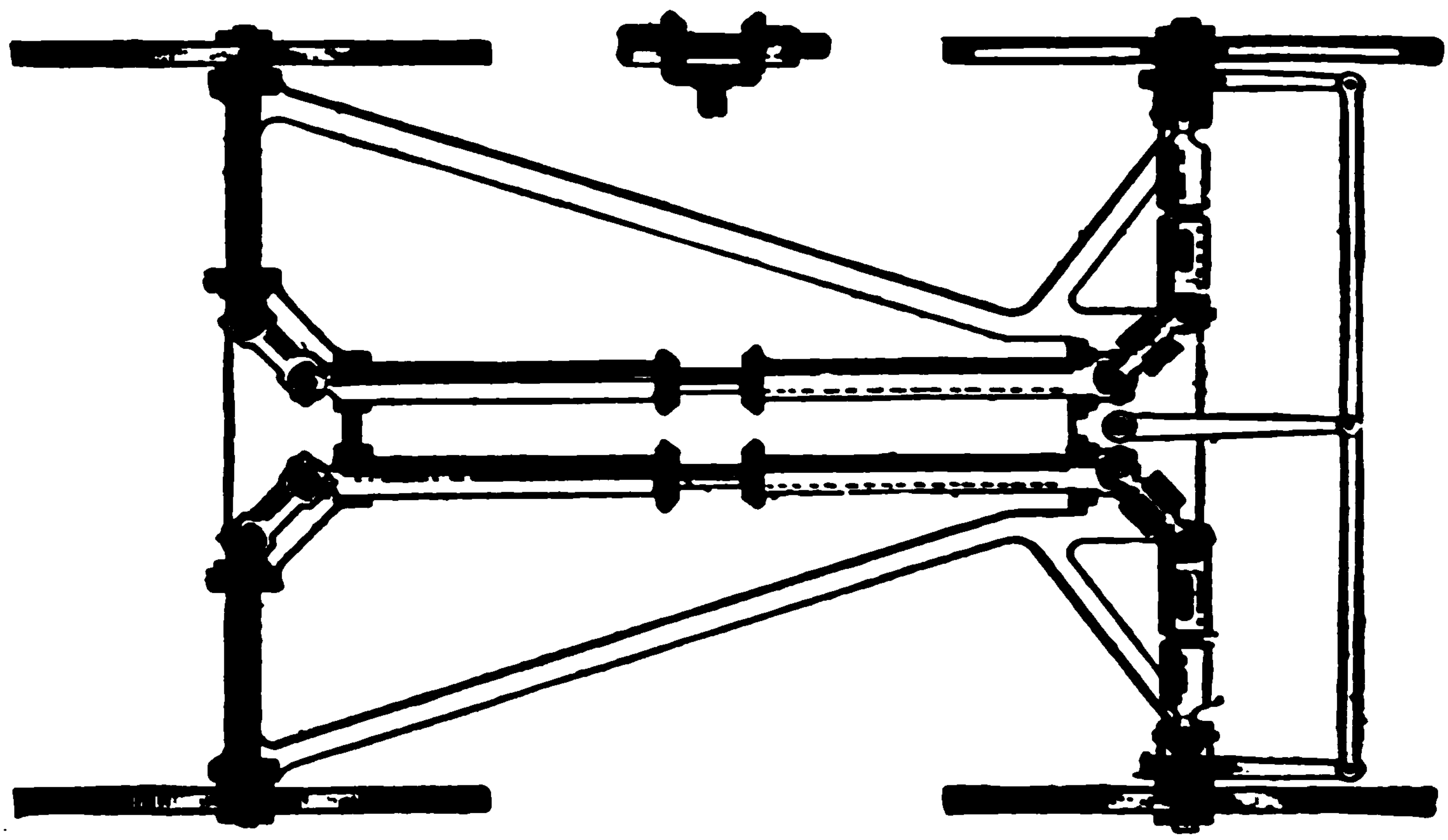


FIG. 60.—Recently Patented Device for Driving on all Four Wheels by a System of Universal Joints. The steering arms are not inclined, since the wheels being driven follow their paths without slipping.

and transmitting the rotative movement from two separate trains of bevel gears to the front and rear wheels by sets of universal joints. The front wheels rotate in pivoted bearings, so as to be effectually turned in steering, without interfering with their motion on their own axes, or in any way altering the action of the motor. Furthermore, a proper arrangement of bevel gearing at the pinions attached to the rotating shafts and sleeves will give the effect of compensating the speeds of the two rear wheels in turning, according to the principles previously explained.

It would be perfectly simple to hang all four wheels on stud axles and give them steering inclination by means of transverse drag-links; operating both links from a common steering hand-wheel or tiller.

# CHAPTER SEVEN.

## THE SUPPORTS OF A MOTOR VEHICLE.

**Underframes and Springs.**—A few years ago very many automobiles were built with some form of underframe, whose essential elements were perches connecting the front and rear axles, as in most horse carriages, and some form of swivel joint to permit of considerable distortion, in compensation for unevenness on the roadway. The two objects sought in this supposedly necessary structure were strength and flexibility. Very many designers also used complicated frameworks of steel tubing, with the additional object of securing lightness. These elements have now been almost entirely abandoned, except in a few light steam carriages and some electric wagons, since designers have learned by experience that with properly arranged springs a motor vehicle can be strong and flexible, without perches or swivels, and light, without steel tubing.

**Advantages of an Underframe.**—In one very essential particular, however, the underframe was a desirable complication. In the greater number of cases it embodied an approximation of the essential principle of three-point support for the body and machinery, which is not always perfectly attained in more recent constructions. Thus, the typical underframe for light carriages had longitudinal perches converging in a swivel joint at the centre of the forward axle. Others had two such perches swiveled to the axle. In either case the three-point support was partially provided under conditions involving lateral distortion of the running gear, in spite of the inevitable stiffness of all such frames and the indifferent efficiency of the swivel joints.

**Three-Point Support.**—Three-point support is desirable from the fact that, whatever the strain and distortion encountered, the three points always fall in one plane. If an object rests evenly upon four points, it is evident that any force acting to remove one of the supports tends to destroy the stability and throw the body into a plane at an angle with the plane of the other three supports. If, on the other hand, its weight be evenly distributed between three points, it is adequately supported on any

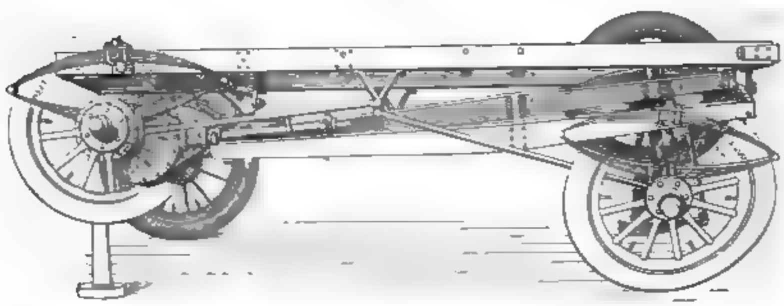


FIG. 61.—Marmon Double Three-Point Support.

plane, and a force, acting unduly on one of the points, cannot draw away the support—rather drawing the supported body in the direction of its moving stress.

One of the most notable applications of the principle of three-point support is found in the Marmon car. Here a triangular under frame is swivelled around the propeller shaft at the rear and supported on the elliptical springs over the front axle. The body frame is supported over the rear springs, and swivelled to the base of the triangular under frame at the front. This arrangement assumes the horizontal position of the engine and body, no matter what obstructions are encountered by the wheels.

**Three-Wheel Carriages.**—From such facts we are able to apprehend the logical force behind some of the leading arguments

for the three-wheeled carriage. As already suggested in a former chapter, it embodies the theoretical requirements of easy steering, and, contrary to first supposition, is less easily upset. Charles E. Duryea, the leading advocate of this type of vehicle, says:

"The future popular two-passenger carriage will be a three-wheeler, because of the many advantages which only need to be known to be appreciated. * * * * * The three-wheeled carriage, if properly designed, rides as easy as a four-wheeler, or so nearly so that the difference cannot be told by a blindfolded observer riding in the two alternately; while the three-wheeler steers more easily, requires less power to propel, starts and stops more quickly, is simpler, lighter, very much better in mud and appreciably better everywhere else."

Commenting on the bicycle traditions, formerly prominent in automobile construction, Mr. Duryea says again:

"Engineers make a mistake who attempt to apply their experience indiscriminately to carriages, for the carriage problem is not a single-plane problem. Both the cycle and its wheels receive strains, and in a single plane, while cycle riders save themselves and the machine by standing on the pedals on rough spots. The automobile rider never does this, while the constant torsions and wrenchings of a four-cornered frame are simply indescribable. On this account a three-wheeled construction is much longer lived and will undoubtedly prevail in the end."

**The Chassis and Springs.**—At the present day light carriages are most often constructed with long side-spring perches between the axles and have the body supported on a flat frame midway in their length. With heavy carriages the body rests on a rectangular framework of iron or steel that is directly supported on the springs attached to front and rear axles, forming the "chassis," or running gear. With either construction compensation of different levels is possible, as in riding along the side of a slope or going over a rock in one of the wheel tracks, the springs serving the double purpose of absorbing the jars of travel and giving the running gear a necessary degree of distortability.

**Construction of Springs.**—The leaf springs used in road carriages and railroad cars consist of several layers of steel plates or

leaves more often slightly bent, so that, when laid together, they are found forming superposed arcs of so many concentric circles. It is essential to a serviceable spring of this description that the line of the arc be carefully followed from end to end of each plate, and that no attempt be made to straighten or bend back the extremities of the longest leaves. This is true because the spring effect is derived from the temper of the metal in permitting the load to flatten all the arcs at once under a single stress, which

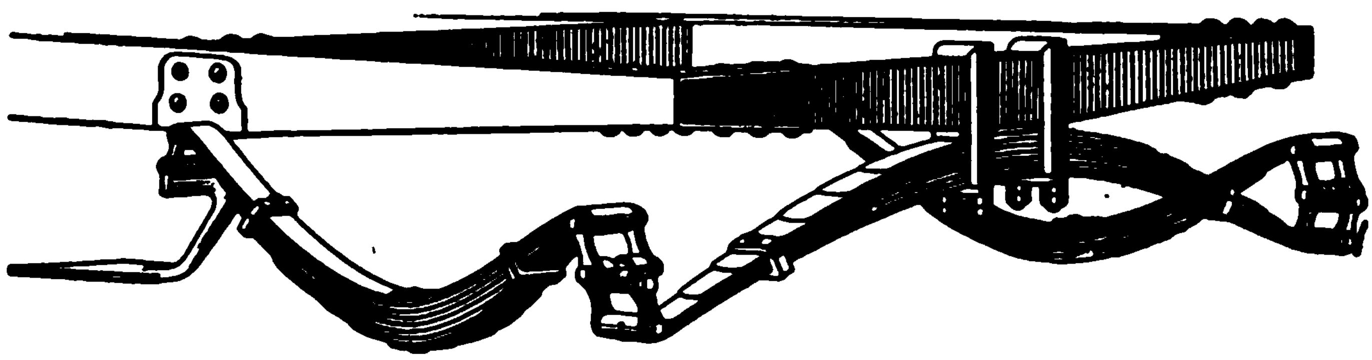


FIG 62.–Three-point suspended spring, or platform spring, one of the latest and most conspicuous improvements in spring suspension designs.

involves that they should slide upon one another in altering their shape, as could not be the case were there any such departure from the line of the arc, as has been mentioned. In that case the several plates would tend to separate and "gape" under a load requiring a degree of compression tending to bring the extremity of any arc to the straight portion of the top leaves. The result would be a loss in spring action, and a probable source of breakage on occasion.

**The Construction of Springs.**—In constructing laminated leaf springs it is essential that the plates should decrease on a regular scale of lengths, in order that the structure may be of equal strength throughout and of sufficient flexibility for the loads calculated to its dimensions. Where such a spring is thick, consisting of a number of plates, it is a good working rule that the ends of each several plates should touch the sides of a triangle,

whose base is drawn between the extremities of the longest plate and whose apex is at or about the theoretical centre point of the spring's movement. This means that, with a well-proportioned spring in its normal shape, the end of each separate plate should be equidistant from that of the one immediately above it and of the one immediately below it. By this construction even distribution of stress is attained without waste or resistance from inactive portions of the length of each plate, as would be the case in a laminated spring flattened at the top plate and having the longitudinal profile shaped to an arc. Such a spring, however,

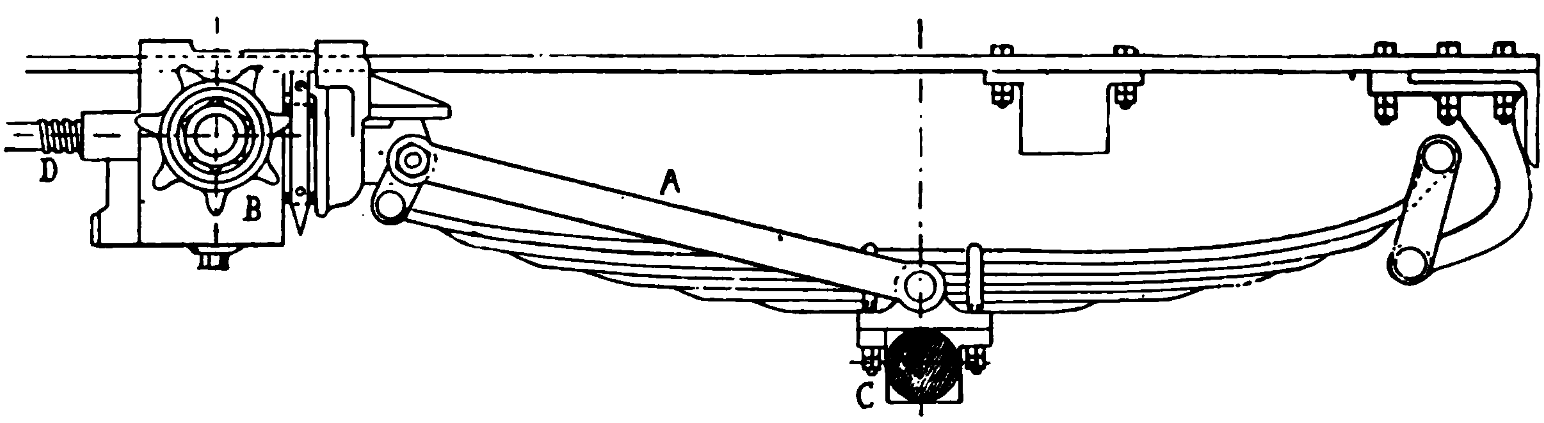



FIG. 63.—Semi-elliptical Spring and Radius Rod of the Mors Cars. The rod, A, maintains a fixed distance between the sprocket pinion, B, and the wheel axle, C, even when the springs are constantly in action. This carriage also has a device for varying the distance between the countershaft at B, and the engine pulley, by sliding the entire shaft forward or back under impulse from the screw, D. The spring, being hung on links at front and rear, has considerable play, up and down, without disturbing the fixed relation of the axle, C, and the countershaft, B, as determined by the radius rod, A.

would embody bad construction in another particular, since it would neglect one very essential feature of spring construction—curvature of the plates. This curvature is intended to represent the difference between the spring under static and maximum load; at the latter point its leaves should be nearly straightened under stress; beyond that point, as they are bent backward and downward, the point of ultimate strength, involving loss of elasticity and breakage, is rapidly approached. It follows, therefore, that the end of a perfectly elastic and serviceable spring is best attained by such curvature as will allow bending of the plates from each extremity of the top plates, on the support at the centre,

without involving endwise compression, as is the case when the curve approaches a semi-circular contour. Consequently, laminated leaf springs are usually constructed to an arc of never more than ninety degrees and often very much less.

According to arrangement, there are three varieties of leaf spring used on automobiles: elliptical, semi-elliptical and scroll.

THE SEMI-ELLIPTICAL SPRING consists of a segment formed by a number of leaves or blades, and is arranged to be attached at the bottom and the two extremities of the arc.

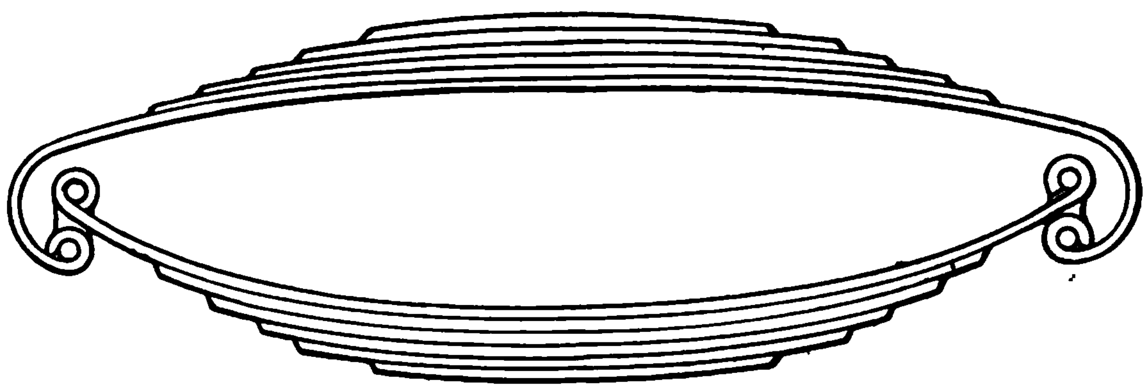


FIG. 64.—Scroll-elliptic Rear Axle Rear Spring used on models of the Packard Light Car.. The C-shaped upper portion is connected by shackles to the elliptical lower half, the effect being to allow the use of fixed distance rods and keep the chain taut, without the use of the usual devices of foreign and American carriages.

THE ELLIPTICAL SPRING is formed by connecting two semi-elliptics or arc-shaped springs at their extremities—generally by bolts passed through perforated bosses formed at the extremities of the longest leaves—and is attached at the apex of each arc by clips or nuts.

. THE SCROLL SPRING differs from the semi-elliptic in having one extremity of the arc rolled up and turned inward. It may be attached by a link or a shackle to a flat or semi-elliptical spring —forming a "scroll-elliptic"—or to the body suspended above the axle.

**Springs on Motor Carriages.**—We may readily understand that motor carriages, being intended primarily for high rates of speed, involve spring conditions found in neither horse-drawn vehicles nor railroad cars. The latter, although traveling at speeds often 100 per cent. greater than the average automobile,

run upon an even and comparatively unresistant roadway—the track of steel rails—while the former, although built for the ordinary highways, as are automobiles, are seldom calculated for any but very moderate rates of speed. Railroad cars must thus provide against a maximum speed, with a minimum road roughness and resistance; horse carriages, on the other hand, must provide against maximum roughness and resistance with minimum speed; motor carriages must be able to attain high speeds and, at the same time, resist the annoying and destructive effects of roadways, inevitably irregular as to resistance and other conditions

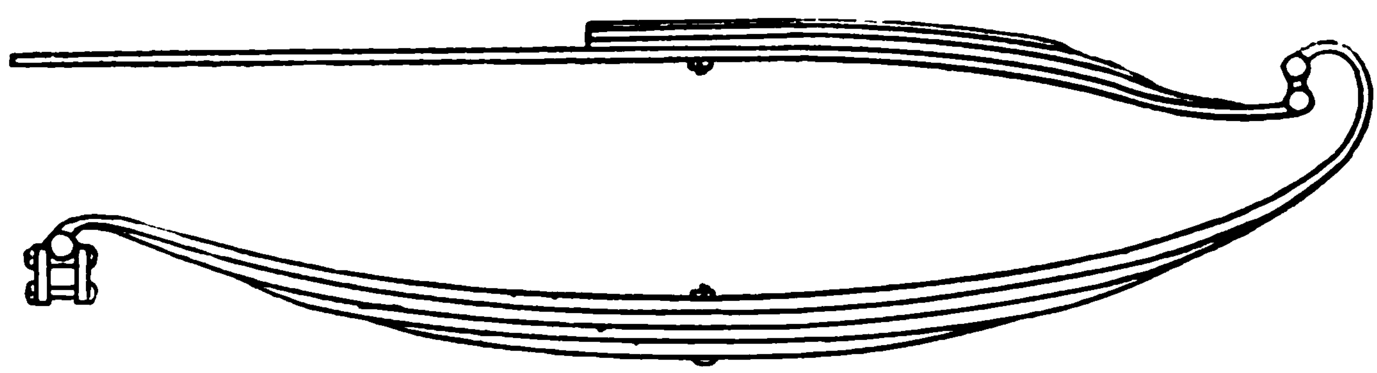


FIG. 65.—Scroll Bottom Carriage Spring, half elliptic, showing connections by links and shackles.

of surface. As a general proposition, therefore, we may assert that such springs as will promote comfort will prevent undue wear and tear on the motor and parts, which, in fact, makes the end of easy riding for the passengers the prime consideration.

**Resistance and Resilience.**—To be thoroughly serviceable, a spring should possess two essential qualities in due proportion: resistance and resilience. While a spring should be calculated to give sufficiently to absorb the jars of travel, it should not be so resilient as to rebound with a series of oscillations. This produces a movement that is liable to be extremely annoying, while, at the same time, contributing nothing to protecting the mechanism. As a good general rule, the best spring is one that "moves quickly, when idle or worked on, and slowly, when working"; that is to say, one that absorbs jars by friction between its leaves, rather than transforming them into a series of jumps. The "happy mean," therefore, lies between the extremes of over-sensitiveness and over-rigidity

**The Action of Springs.**—In this connection it is desirable to remark that good spring action can be obtained only with springs adapted by weight and elasticity for the work required in any given case. The efficiency of a spring can never be increased by oiling between the leaves, since it will not give, except under sufficient load, and, even then, the friction of each leaf upon its neighbor is an essential part in the work of absorbing jars. As some writers have expressed it, the jars of travel are transformed into heat by this friction. At the same time the danger that it will wear out the spring is exceedingly remote.

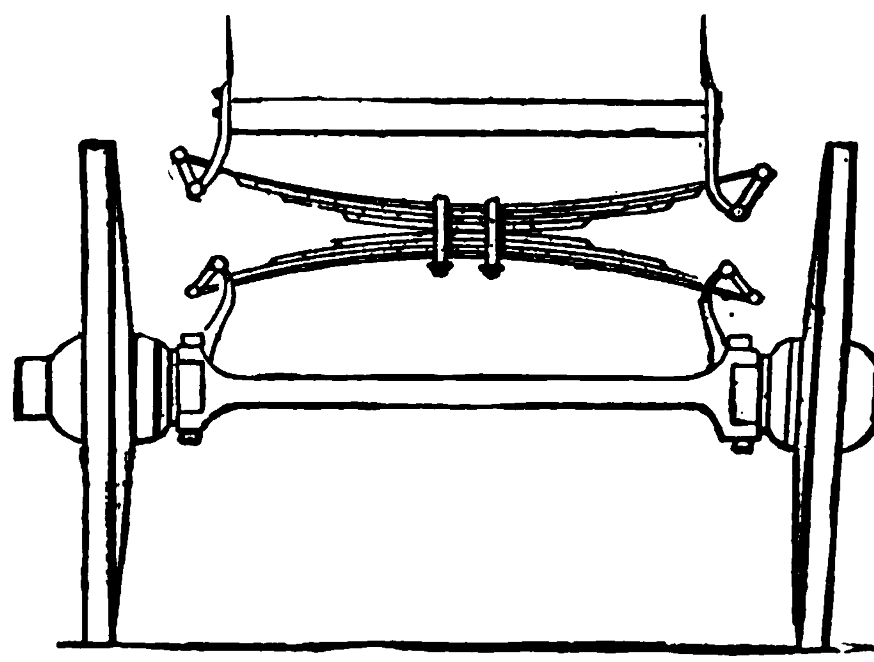


FIG. 66.—Double semi-elliptical spring attachments used on some electric vehicles. The body, being suspended entirely by links on the extremities of the springs, has the full benefit of spring action.

**Considerations in Spring Design.**—Apart from certain well ascertained figures on the static weight of the load and the size and tensile strength of the springs designed to carry it, there are no reliable data regarding the proper proportions of springs for automobile carriages. As we have said, this is and must continue a matter to be governed most largely by experiment, apart from mathematical calculations, since the constantly varying conditions of automobile travel preclude exact theory. Among these variants may be mentioned high speeds on any and every kind of road and the use of pneumatic tires. The matter is still further qualified by the size of the tires and the degree of inflation, for both of these points are important in modifying the stress to

come upon the springs. Indeed, there is no more important factor in the high-speed motor vehicles than the rubber tires, although the properties developed in its practical operation by no means permit its use on vehicles without suspension springs of some description.

**The Effects of Pneumatic Tires.**—The use of pneumatic tires on a vehicle permits the absorption of considerable vibration and the consequent use of softer springs than are possible with steel tires. One reason for this is that pneumatic tires, after violent or unusual compression, do not rebound, as even the best springs will do, whence only a minute portion of the total shock

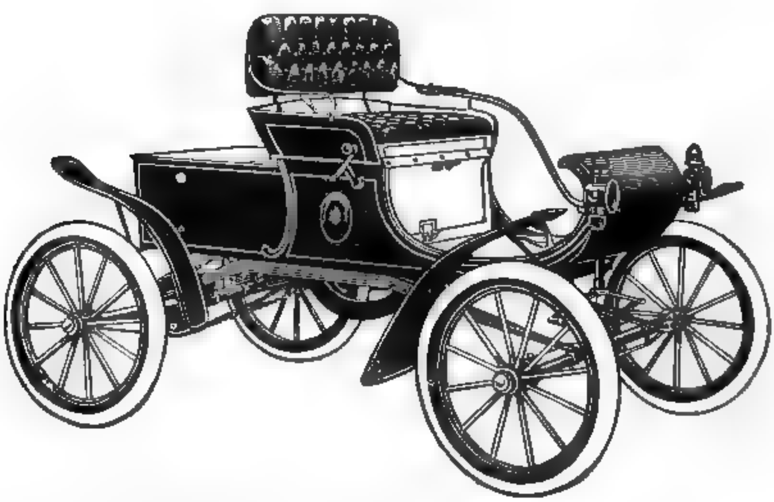


FIG. 67.—Oldsmobile Runabout, showing side-spring-reach suspension of the body between the axles; also, the elliptical compensating spring on the steering pillar.

is transmitted from them to the springs. On the other hand, they frequently develop a certain bouncing motion, which is imparted to the running gear, and will occasion an annoying back jolt. This is entirely neutralized by the use of properly adjusted springs, although in the matter of adjustment we must calculate

as essential elements the size and degree of inflation of the tires, the weight and dimensions of the springs, and the average speed used. In some respects a heavier spring gives easier riding than a light one, since the latter is apt to bounce disproportionately, even with good pneumatic tires, when the road is somewhat rough.

**Condition of Spring Dimensions.**—In judging of the dimensions and elasticity of springs suitable for carriage use, the limit of elasticity must be carefully considered with relation to the static and maximum loads to be carried by the vehicle.

THE STATIC LOAD is the dead weight of the vehicle body and frame, together with that of the passengers and other freight, estimated when at rest.

THE MAXIMUM LOAD is the proportionately increased weight of the same items, with relation to the traction effort required when the vehicle is running at its highest speed, under test conditions as to road roughness or hill-climbing requirements.

THE ULTIMATE LOAD is the greatest weight possibly carried with good spring action; the limit of the spring's endurance.

That the springs should be calculated to retain the elasticity, or have the ultimate strength far beyond the maximum load, is obvious, when we consider the office of a spring. In calculating the proportions of springs in the best constructed railroads, it is usually customary to consider the maximum load as twice the static load. Whence it is the general practice to estimate the fitness of a given spring for its work as equivalent to the quotient of the weight of the spring divided by the product of its length, between the extremities of the longest leaf, and the number, width and thickness of the other several leaves.

**Proportionate Loads.**—The variable nature of carriage roads makes the proportion of static and maximum load much higher for horse-drawn vehicles than for railway cars, except where

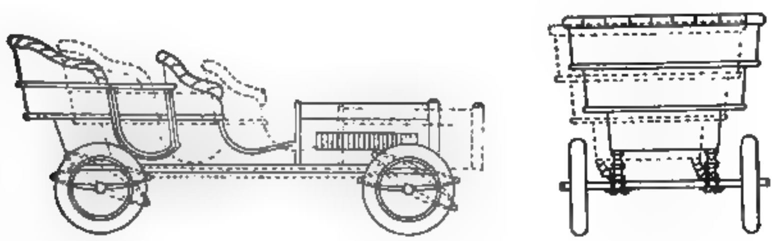
only the most moderate speeds are to be used; but for automobiles always calculated for high speeds, it never falls below a ratio of 1 to 3, and is often estimated as high as 1 to 5.

**Adjusting Weights.**—As has been pointed out by several authorities, the difficulty of obtaining springs for automobiles, which shall be serviceable under all conditions, is greatly increased when the weight of the body, motors, etc., is very much in excess of that of the passengers provided for. This is true, since a spring that will subserve the end of easy riding under usual conditions, with extra heavy accessories of this description, would permit no end of jolting and annoying vibration at high speeds on imperfect roads. The fault is difficult to discover except under test conditions.

**Placing Springs.**—To sum up the general requirements in a few words, we may say that, while pneumatic tires will absorb very many vibrations, thus permitting soft and light springs under the body, the occasional inequalities in the road are liable to occasion a quick succession of annoying jolts, reaching by accumulated forces almost to the limit of spring elasticity, or succeeding one another so rapidly, at high speed, that the springs have little time to recover their normal shape. This seems to indicate that a heavier spring is preferable, or else that spring construction must be in some way varied to give firmer attachments and more evenly distributed elasticity; the time required by the spring to recover itself being the same under all conditions, some springs are thus unfit for high speed work. Many manufacturers prefer semi-elliptical springs to the full elliptical, on the ground that their elasticity is greater for a given weight of spring, and the consensus of opinion on the latter is that the longer the spring, within reasonable limits, the greater the combined elasticity and lightness. When such springs are used as side supports it is general practice to attach one end direct to the longitudinal frame and connect the other by a link, thus allowing ample freedom toward lengthening. When placed transversely over

the forward axle both ends are secured to links, the centre being securely clamped.

**Rules for Calculating Springs.**—As a general proposition, the usefulness of a spring for given work and load is largely a consideration of the total length of the structure between points of attachment. However, the thickness and number of the leaves, and the quality of the steel used—the last-named consideration is of the utmost importance—enter into the formulæ followed in railroad work and carriage designing. These same formulæ are useful to the automobile builder. They may be summarized as follows:



FIGS 68 and 69.—Diagrams illustrating the forward and backward lunges of the body of a motor carriage in travel, with indication of the distortion of elliptical springs. See Page 82

Let B represent the breadth of the plates in inches.

Let T represent the thickness of each in sixteenths of an inch.

Let N represent the number of plates in the spring.

Let S represent the working span, or the distance between the centres of the spring hangers, when the spring is loaded.

Let W represent the working strength of a given spring.

Let E represent the elasticity of the spring in inches per ton.

THE ELASTICITY OR DEFLECTION of a given spring is found by the following formula:

$$1.66 \frac{S^3}{N\ B\ T^3} = E \text{ in 16th inch per ton load.}$$

Other authorities give the formula:

$$\frac{S^3}{C\ N\ B\ T^3} = E \text{ in inches per ton load.}$$

Here C represents the constant 40,000 for single and 20,000 for double springs, and T, the thickness of each plate in inches or fractions of an inch.

THE SPAN LENGTH due to a given elasticity and number and size of plates is as follows:

$$\sqrt[3]{\frac{E\,B\,N\,T^3}{1.66}} = S \text{ in inches.}$$

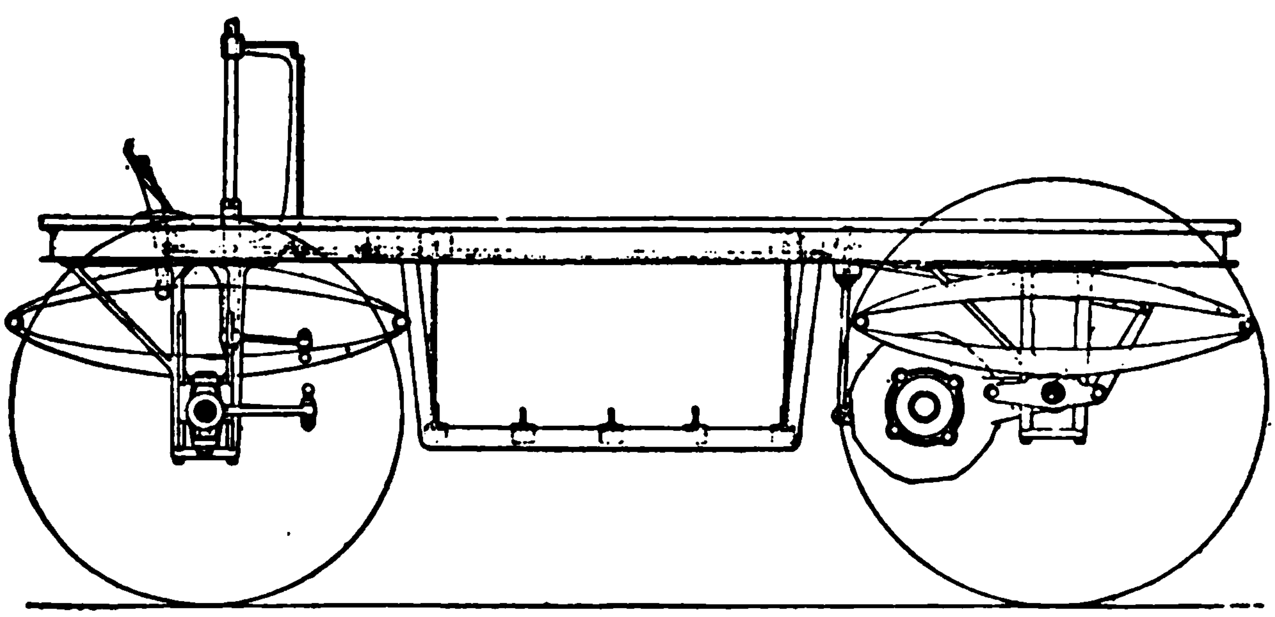


FIG. 70.—The Rainier Pedestal Frame, designed to control the movement of elliptical springs, preventing all distortions in travel.

THE NUMBER OF PLATES due to a given elasticity, span and size of plates:

$$\frac{S^3 \times 1.66}{E\,B\,T^3} = N$$

THE WORKING STRENGTH, or greatest weight a spring can bear, is determined as follows:

$$\frac{B\,T^2\,N}{11.3\,S} = W \text{ in tons (2,240 lbs.) burden.}$$

THE SPAN DUE TO A GIVEN STRENGTH, and number and size of plates:

$$\frac{B\,T^2\,N}{11.3\,W} = S \text{ in inches.}$$

THE NUMBER OF PLATES suited to a given strength, span and size of plates:

$$\frac{11.3\ W\ S}{B\ T^2} = N.$$

**The Cut-and-Try Method.**—A prominent American manufacturer of carriage springs, the Tuthill Spring Co., underrates the value of formulæ like the above, insisting that experiment alone can completely solve the matter. They make the carrying capacity of a spring dependent upon the following conditions:

1. Upon the length of the spring, because a longer spring is limberer than a shorter spring.

2. Upon the width of the steel, a wider one being stiffer than a narrower one.

3. Upon the number of plates, more plates being stiffer than fewer plates.

4. Upon the opening of the spring (or degree of curve), because the nearer it approximates a straight line the limberer it is.

5. Upon the thickness of the individual plates, because a greater number of thin plates, making a given thickness, is equal to a smaller number of thick plates and will be more elastic.

6. Upon whether a lubricant is used between the leaves or not.

**Points on Spring Suspension.**—As regards the suspension of springs of horse-drawn vehicles and automobiles, the careful observer will note one point of divergence at once. When elliptic, or semi-elliptic, springs of the ordinary description are used, he will see that in most light horse carriages only two are suspended, one over each of the axle shafts, across the width of the carriage. In automobiles of every build and motive power, while a single spring may be thus attached to the forward axle, the rear axle supports two, one at each side of the frame, and running in the length of the carriage. This is a construction found only in the heavier patterns of horse-drawn carriages, and in both cases it is resorted to for the purpose of neutralizing the forward

lunge of the body, inevitable on rough roads with a single transverse elliptical spring. With the horse carriage of the heavier pattern such vibration is annoying and also hurtful to the body, frame and springs. With the automobile, however, the case is even graver; for not only will similar results follow at high speed, but the proper distance between the motor, usually carried in the body above the springs, and the rear axle, will be continually disturbed, with consequent damage to sprocket, chain and gears and loss of a steady drive. Thus, in carriages which have no other provision against this tendency of the rear axle to throw backward or forward under the stress of travel, it is necessary to use a device known as a *distance rod* to maintain a fixed distance between motor and drive axle, when the throw of the springs would otherwise permit it to be disturbed. The better method of overcoming this danger is to set the springs in the length of the carriage, as just described; for thus most of the violent jars in this direction are absorbed, and the fixed relation of motor and axle maintained, without rigid attachments, which would form another notable occasion of accidents. This allows the springs to lengthen under pressure from above or from the direction of travel, and further reinforces against sidewise lunges, which, however, are of far less frequent occurrence.

**Attachments for Springs.**—The ends of ready lengthening and extra elastic support are to be accomplished by the use of scroll elliptics and semi-elliptics, connected to the carriage body by suitable links. Links are preferable in many places on account of the ready action allowed in several directions, without involving tendency to yield unduly under ordinary conditions. The high speed requirements of motor carriages makes it nearly imperative that leaf springs, either half or full elliptic, should be securely clamped to the supports by clips and nuts, rather than by bolts through bolt holes in the centre. This is true because such bolt holes are liable to prove a source of weakness under high speed conditions and to cause the breaking of springs at the very time when their full strength is most requisite. With clips

this danger is wholly averted, and, instead of a weak point at the centre, an additional reinforcement is obtained.

**The Alignment of Springs.**—In the act of passing over an obstruction, such as a large stone in the roadway, it is evident that the spring above the axle of the wheel that rises must be compressed to an extraordinary degree, unless it is so rigid as to lift the corner of the vehicle body to a corresponding degree. In either event, as is evident, there must be some sidewise distortion of the spring, which, often repeated, must occasion its destruction. Because an automobile is not usually built for rough roads, few provisions have been made against mishaps from this cause. It is a matter, however, that should interest the practical automobilist, particularly a person about to order a machine built for use in a hilly country, or for long-distance touring. In all such cases there should be some means for keeping the springs working in a perfectly vertical line.

**Stresses on Springs.**—The exact nature of the stresses brought to bear on the springs of a motor carriage are shown diagrammatically in Fig 68. The distortion of a full-ellipitical spring, which from its structural elements allows greater action in every direction, is forwards, when some obstacle, met by forward or rear wheel, tends to throw the body by its own momentum, and sidewise, owing to the action of forces precisely similar to those causing side-slipping of the wheels. The effect of an obstacle met by the wheels would be a bending-forward of the upper front and lower rear portions of the ellipitical springs, tending to bend the entire structure forward and downward, as shown in the figure. This action is intensified in the case of the rear wheels, because they bear the greater part of the load.

The use of semi-ellipitical springs partly neutralizes these tendencies, also reducing the danger of breakage, owing to the facts:

1. That a stiffer spring is required.

2. That a good proportion of the stresses work downward.

**A Three-Spring Suspension.**—A noteworthy attempt to neutralize the tendencies to hinges, forward and sidewise, is found in the Hill spring suspension system, shown in Fig. 71. The front and rear springs are pivoted and linked to the frame by one extremity of each; the opposite extremities are underhung by links to a semi-elliptical spring—the "equalizing spring"—clipped midway to the side-bar of the body frame. The vehicle body is thus supported at three points on either side, at the two ends and in the middle, with the result that any stress exerted at one of the points will be equalized by being transmitted to the two others. It forms in fact, a spring running gear. The result is that stresses, which

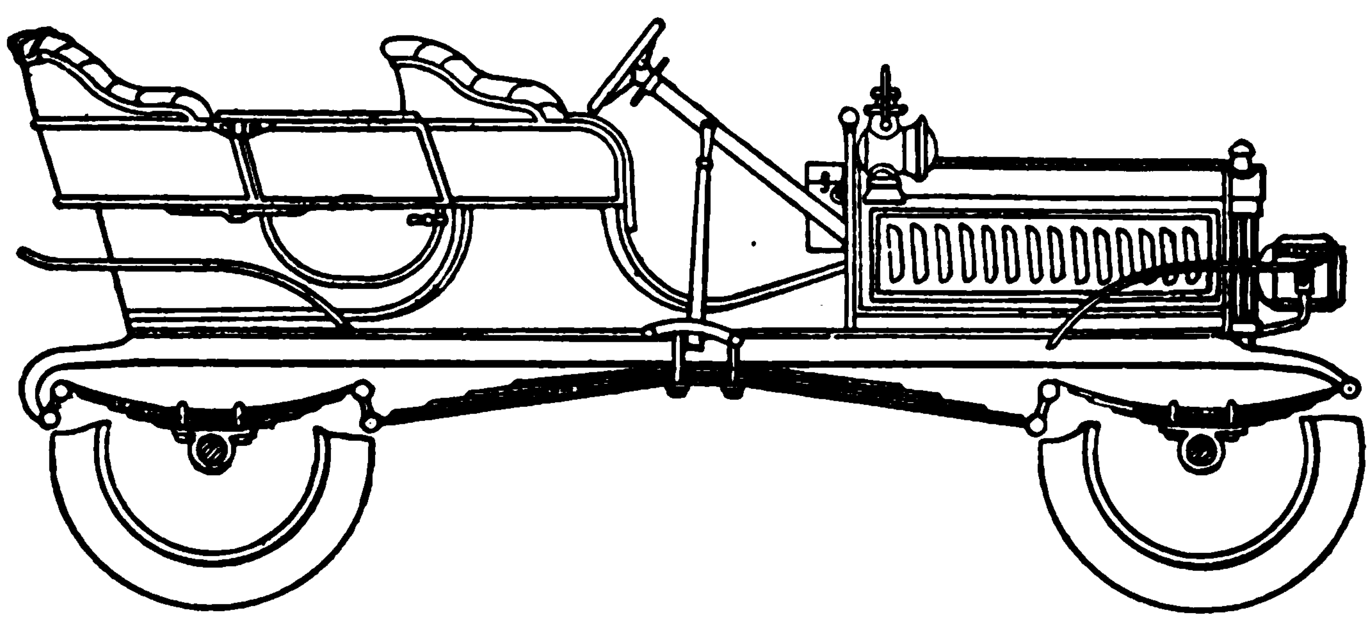


FIG. 71—The Hill three-point-suspended spring device; intended to compensate spring movements and to distribute stresses.

would infallibly distort an ordinary full-elliptical spring, are distributed evenly: the equalizing spring acting in all such cases to restrain any excessive movement, caused either by the vibrations of travel or by motor thrust, and compelling the front and rear springs to lengthen under all stresses.

**Pedestal Spring Frames.**—Another noteworthy device is that embodied in the Herschmann steam truck. Instead of the usual rigid attachment by bolts, the spring has on its lower face a semi-cylindrical shoe that rests loosely upon a flattened portion at the top of the axle shaft. The axle works up and down between guides, four in number, at either side of the vehicle, and formed of angle or L-shaped iron rods. The spring is bolted between cross-shaped clip plates, the lower of which carries the

shoe above mentioned, and by this means its movement is confined in one vertical plane. With any elevation of one wheel, the axle works against the shoe, merely lifting the spring, without twisting or distorting it sidewise. The Rainier "pedestal frame" similarly provides against other than vertical movement of the springs and axles by two vertical guides extending downward from the steel frame outside the springs. A flattened portion of the axle-tree works up and down between these guides.

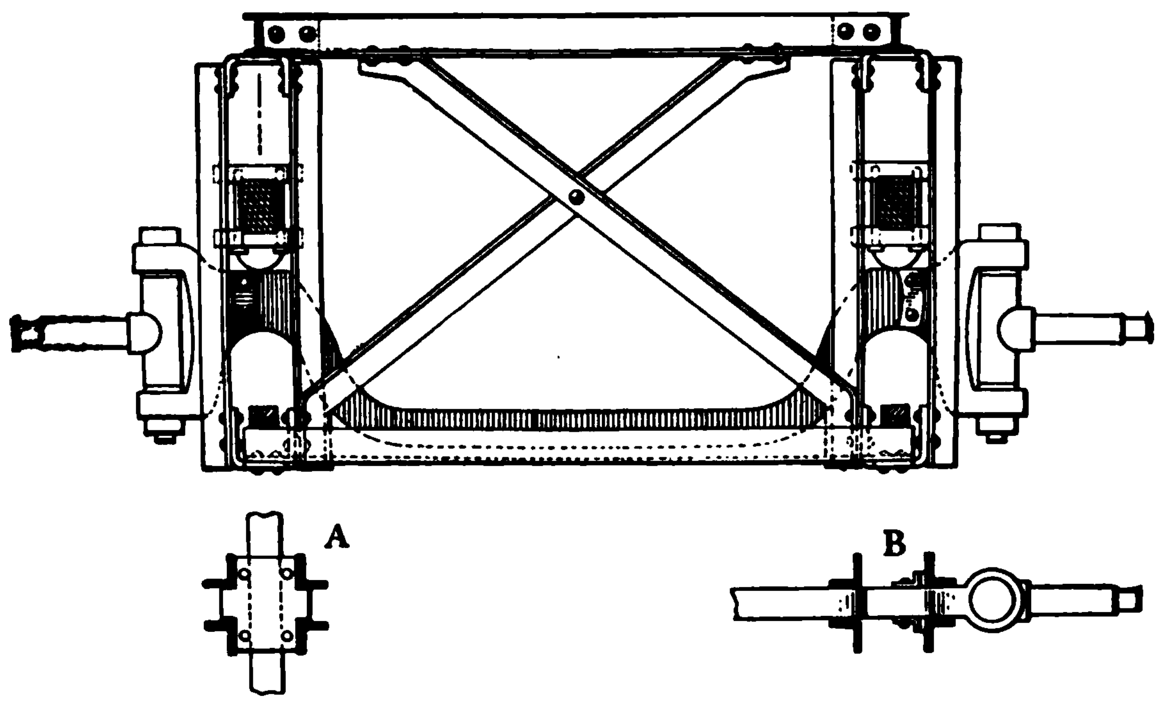



FIG. 72.—The Herschmann spring pedestal device; showing springs resting loose on the axle, their movements being confined to the vertical by guides. All throws of the vehicle body in travel are overcome by this arrangement.

**Supplementary Springs.**—A recently-introduced device substitutes for the shackle a coil compression spring arrangement, so mounted on a frame that the upper member of a scroll-elliptic, or the spring hanger extending from the body frame, is attached to one end of the coil spring, and the lower member to the other. The coil is compressed under stress of travel absorbing jars, otherwise transmitted to the body and motor.

A devise somewhat similar in effect has been used on models of Mercedes car. An elliptical spring has two small semi-elliptics clipped and bolted inside the arcs of its two members in such position as to meet and engage, when extraordinary stresses tend to depress the main spring, thus absorbing heavy jars and preventing excessive flattening out. The two smaller springs are called the "check springs." One American manufacturer has

produced a similar device by the use of a large coiled spring, instead of the two small laminated springs of the Mercedes.

Winton's twin compound spring is an even better solution of the problem of varying loads. Briefly described, it consists of two three-leaf semi-elliptics—the upper somewhat longer than the under—which are joined by shackles at the extremities and attached to the spring supports of the frame. With a light load, under ordinary road conditions, the upper spring alone is in action. When, however, the load increases to a point at which it begins to straighten out, the lower spring begins to receive its share of the load, thereby doubling the resistance of the support. The effect of perfect compensation is thus obtained, along

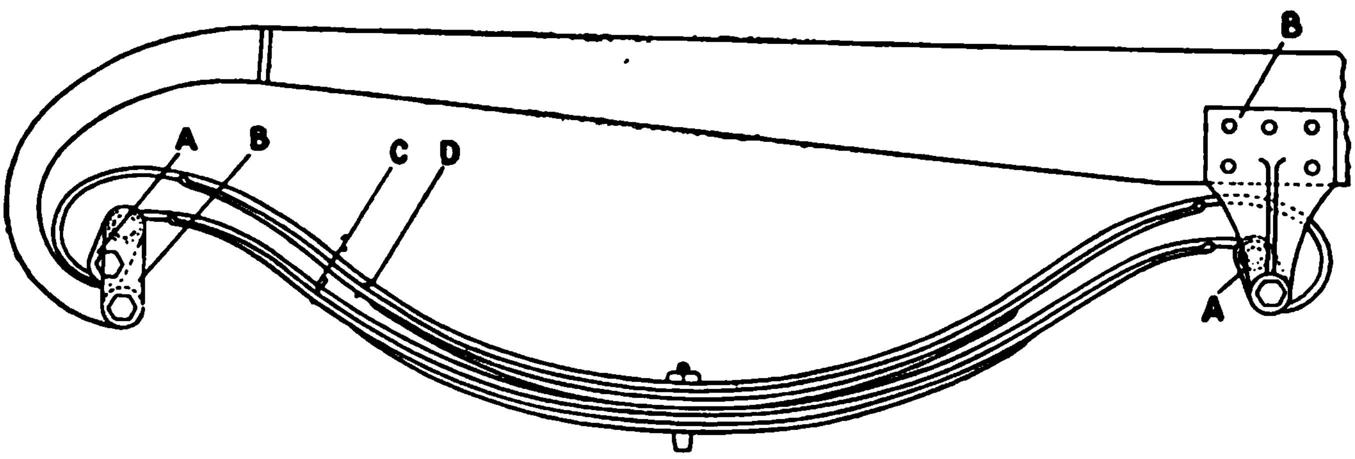



FIG. 73.—Winton's twin compound spring, A and A, links connecting springs, to supports, B and B; C, lower or main spring; D, supplementary spring to take additional loads.

with a practical solution of the serious problem of securing easy riding with either light or heavy load, a thing hitherto impossible. It may be justly claimed that this device combines in unique fashion the essential spring qualities of resistance and resilience.

**Absorbing Vibrations.**—While, as we have seen, a flexible spring is required for the purpose of deadening the numerous annoying and harmful shocks encountered in operating a car over an uneven roadway, excessive flexibility is liable to intensify such movements. A spring serves its function in bending downward, or straightening, under the stress of a moving load, but it shows itself unequal to the task assigned it, when, by continued vibrations, it merely breaks up or distributes the shock in a series of bounds and jolts, destructive alike to body, machinery and tires, and from which there is no relief or protection.

It is obvious that some device for ensuring the gradual return of the spring to its normal shape, deadening its rebounds and after-movements by absorbing them with some form of friction resistance, is highly desirable. Similar results are achieved in other branches of mechanic arts by the use of "dash-pots," etc. Applied to neutralize the rebound, or after-movements of a motor spring, the result is greater comfort for passengers, smaller injury to machinery and nearly double durability of pneumatic tires.

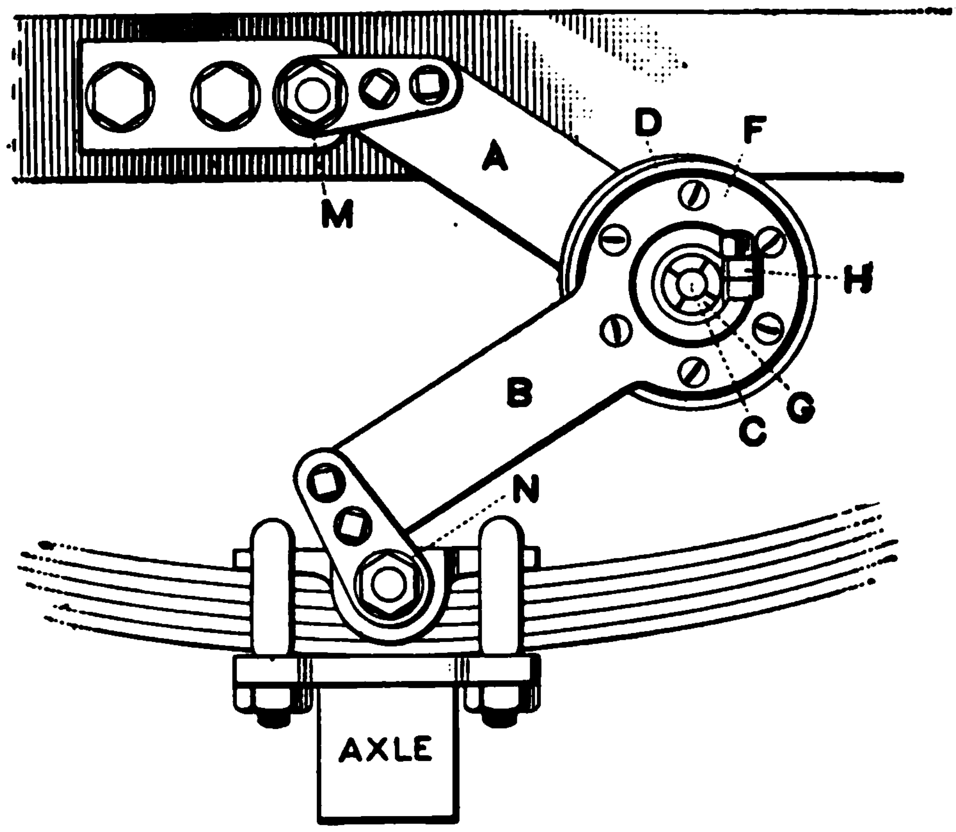



FIG. 74.—The Truffault Spring Suspension for neutralizing shocks due to sudden spring action.

The best-known and most successful of such devices is the Truffault suspension shown in Fig. 74. It first attained distinction through its adoption on Peugeot cars, and has since done excellent service on several others equally prominent.

Briefly described, it consists of the two arms, *A* and *B*, joined frictionally by bolt *C*. The arm, *A*, carries a cup-like bronze shell, *D*, and the arm, *B*, a plate, *F*. A cup-like piece of oil-soaked rawhide is secured between the plate and the shell, being screwed by the nut *G*, on the bolt, *C*. An oil-soaked leather washer separates it from the plate, *F*. This nut is split and is locked in place by the collar, *H*. By screwing sufficiently, the nut, *G*, any desired degree of friction may be obtained. The arms, *A* and *B*, are joined to the frame and the axle by two cone-like frictional joints, which also

can be regulated. All these movable frictional parts offer a constant resistance to the vibration of the spring both ways, and it is easy to see that when the wheel strikes an obstruction the arms come together; but instead of flying back as does the free spring, it is retarded by the friction and moves gradually to its normal position, since the friction is always the same, while the tension of the spring diminishes as it approaches its normal position.

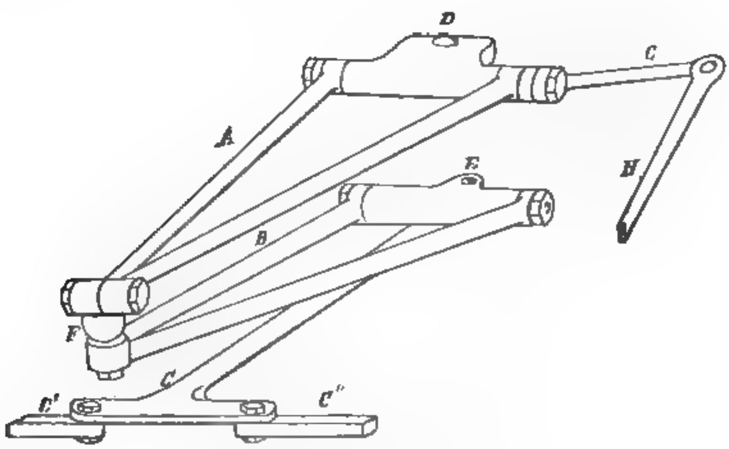


FIG. 75.—The De Dion & Bouton Spring Compensating Steering Device.

**Radius Rods.**—A spring support involves the use of some device for maintaining a fixed distance between the motor and the driven axle. This generally takes the form of a radius rod attached to a bearing at either end, so as to describe an arc, with the rear axle as a centre, while the springs rise or fall in travel. A turnbuckle permits the length of the rod to be varied according to requirements. With the two-chain drive to the rear wheels, loose on a dead axle, two distance rods, one at each end, are usually provided. With a single-chain drive to a live axle one rod usually suffices. With bevel-gear drive a slip joint on the propeller shaft usually suffices to maintain a fixed distance, although, as must be evident, an extra strain is thereby thrown upon the bevel casing, which is only too liable to break, with the other forms of violence it must endure.

**Compensations for the Steering Gear.**—Some automobiles include spring compensating devices for the steering gear, although with modern forms of hand-wheel a link swung between ball joints is amply sufficient. On the lighter forms of De Dion carriage a somewhat complicated although highly efficient compensation was used. As shown in an accompanying figure, a V-shaped piece A, constructed of two pieces, is attached to the tubular front cross-piece of the body frame at D, and pivoted on the ball joint at F, to the lower V-shaped piece, B. This is also pivoted at F, and is attached to the axle-tree at E. The T-piece, C, is also pivoted at E rigidly with B, so as to turn sideways with it. It carries the links C′ and C″, which actuate the steering arms of the two stud axles. The link, H, is at-

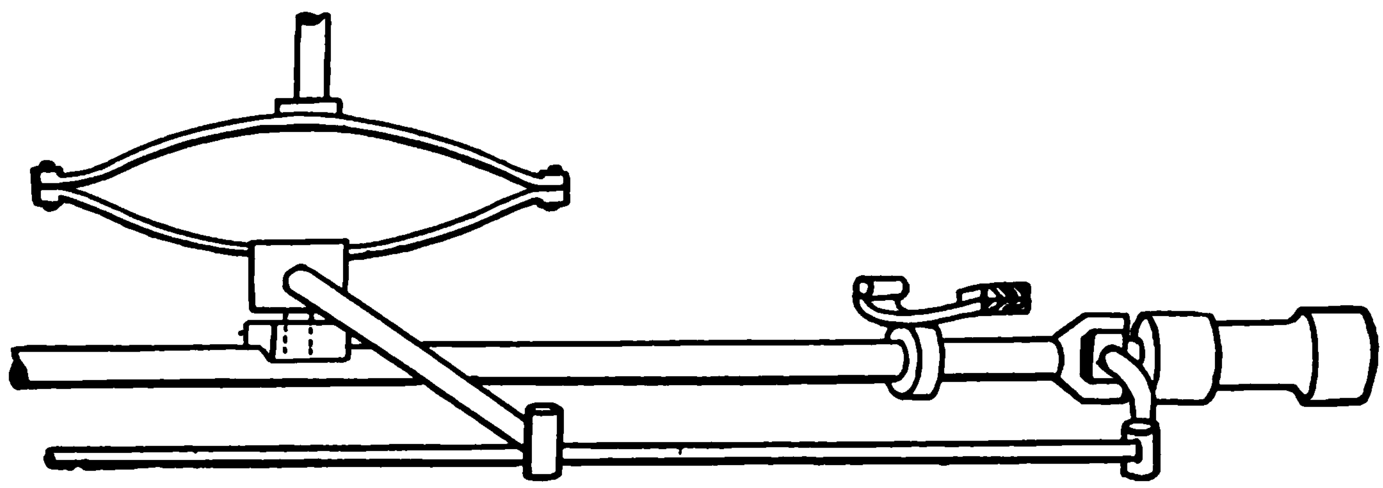


FIG. 76.—Spring Compensating Steering Device used on the Oldsmobile Carriage.

tached to the arm, G, and when moved forward or back by the worm gear and pinion arrangement at the base of the steering-wheel pillar, moves the entire structure, A, B and C, on the pivots, D and E, to the right or left, as desired. The object of the device is to allow of a certain up and down movement, as the springs yield, without disarranging the steering gear or vibrating the steer wheel. In such cases the V-pieces, A and B, move on the ball joint F, thus permitting the points, D and E, to be approached and separated, as the springs move.

In the Oldsmobile, built with longitudinal side springs between the axles, the steering pillar is attached to the front axle through a small elliptic spring, which, bearing against the bottom of the body, is compressed or distended, as it falls or rises, thus enabling the steering to be positive and uninterrupted under all conditions.

# CHAPTER EIGHT.

## MOTOR CARRIAGE WHEELS.

**Requirements in Motor Carriage Wheels.**—Motor carriage wheels must have five qualities of construction:

1. They must be sufficiently strong for the load they are to carry, and for the kind of roads on which they are to run.

2. They must be elastic, or so constructed that the several parts—hub, spokes and felloes, or rim—are susceptible of a certain flexibility in their fixed relations, thus neutralizing much vibration, and allowing the vehicle greater freedom of movement, particularly on short curves and when encountering obstacles.

3. They must, furthermore, be sufficiently light to avoid absorbing unnecessary power in moving.

4. They must be able to resist the torsion of the motor, which always tends to produce a tangential strain. This is the reason why tangent suspended wire wheels are invariably used in automobiles, instead of the other variety, having radially-arranged spokes.

5. They must have sufficient adhesion to drive ahead without unduly absorbing power in overcoming the tendency to slip on an imperfectly resistant road-bed.

The importance of the two last considerations may be readily understood, in view of the fact that the wheels of motor carriages receive the driving power direct, instead of being merely rotating supports, like the wheels of vehicles propelled by an outside tractive force.

**Wooden, Steel and Wire Wheels.**—Motor carriage wheels, at the present time, are either wooden, of the so-called "artillery"

type, or of steel tubing. A few years ago suspended wire wheels, of the bicycle variety, were extensively applied to motor carriages of all powers, and their claims to superiority were vigorously discussed. They are now so seldom seen that, we may unhesitatingly say, they have been abandoned.

**Suspended Wire Wheels.**—Like steel tubular framework, also nearly obsolete, the alleged advantages of wire wheels were given as combined lightness and strength. A suspended wire wheel, weight for weight, can undoubtedly carry a heavier load than a wooden wheel, without danger, but it cannot sustain as great stress sidewise, or at right angles to its plane, which is the line of a wheel's greatest weakness, and, in automobile work, of the greatest stress acting upon it.

A wire wheel driven against a curb with sufficient force will have its rim dented, with the result of loosening all its spokes and ruining it. A wooden wheel, on the other hand, may have a gap in it and still be serviceable. It may even run with one or several spokes broken off. A wire wheel being suspended on its spokes—the load being hung between the hub and the perimeter—is bound to suffer in proportion to the number of points of suspension lost. A wooden wheel, being supported at both hub and perimeter by its spokes, has a certain power of compensating or distributing the strain, so that, while a deficiency of support at any one point is of no advantage, it does not always involve destruction.

**Steel Tubular Wheels.**—Steel tubular wheels, which have been used to a certain extent on automobiles, have the advantage of possessing such strength, particularly in a sidewise direction, as tubular construction possesses, and are immensely superior to wire wheels. Among the advantages claimed are:

1. Superior strength to either wire or wood.

2. True, balanced running, as a pulley on a shaft.

3. Practical immunity from dishing or crushing with the hardest use, or in ordinary accidents.

4. Immunity to rust.

5. Ability to stand the twist and tension of severe strains in the transmission of power.

6. Rims formed from a continuous tube.

7. Perfect alignment of all parts.

Steel wheels are imperfectly elastic, however, and have very little of the desirable spring effect. Thus, while such a wheel, if well made, will endure, without rupture, strains far in excess of those encountered under service conditions, such distortion would result as would unfit it for extended use.

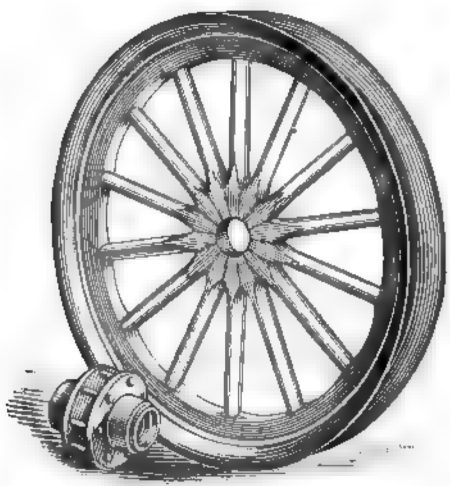


FIG. 77—A typical Wooden Artillery or Wedge Wheel, showing manner of setting the spokes, and the construction of the hub.

Tests conducted, some years since, on one make of steel carriage wheel demonstrated ability to resist a dead weight at the axle up to 3,200 pounds, a sidewise pressure of 1,600 pounds, and a combined pressure at rim and axle up to 3,500 pounds. Beyond these points, however, permanent bending and distortion resulted.

**Wooden Artillery Wheels.**—Wooden wheels are almost universally used for automobiles at the present time. The type in

vogue is the so-called "artillery" wheel, constructed with wedge spokes set together around the nave, and a hub formed of steel plates at front and rear, bolted through the spokes and holding the axle box in place. This is substantially the model originated by Walter Hancock, an early steam carriage builder, and is by far the most solid design of wooden wheel possible. It is, in fact, practically of one piece, having strength to withstand sidewise strains that would speedily wreck a wheel of the type used in horse carriages.

**Dishing of Wheels.**—Where wooden wheels are used in any kind of vehicle, the effect of elasticity is greatly increased by "dishing"; that is, by inclining the spokes from the exterior plane of the rim to the centre point of the axle spindle, so as to make the wheel a kind of flattened cone. This construction has the effect of transforming the spokes into so many springs, possessing elastic properties, and renders the wheel capable of being deformed under sidewise stress. The shocks of collision with obstacles are thus distributed through the flexibly connected parts, as could not be the case if the wheel were made in one piece or on one plane, and the consequent wear and strain is greatly reduced. The dish of the wheels is usually balanced by slightly inclining the axle spindle from its centre line, thus bringing the lowest spoke to a nearly vertical position with relation to the ground. A great resisting power to shocks produced by obstacles such as is afforded by dished wheels is of far less importance in vehicles designed for good roads as are most automobiles, which need only such inclination of the spokes as will provide for the even distribution of shocks and the maintenance of uniformity in pressure.

**Advantages Attained by Dishing.**—The significance of the word "dish" is obvious, when we consider that it indicates a diametrical section of about the shape of a saucer or shallow dish. While, as we have seen, this shape furnishes a very desirable spring effect against sidewise strains and shocks, such as are met in swinging around a corner or sliding against a curb—since, although a wheel is always weakest sidewise, it is difficult to

thrust a cone inside out—there are several considerations that render it a desirable feature for wagons of all descriptions.

1. The first of these has reference to maintaining a balanced hang to the wheel. Under the conditions of travel a wheel acquires the tendency to crowd on or off the spindle, with the result that it eventually wears loose, as may be frequently found, particularly on heavy carts. Since the spindle is tapered it is necessary that its outer centre should be lower than the inner, and then in order to counteract the outward inclination of the wheel, and consequent tendency to roll outwardly, the spindle end must be also carried forward sufficiently to make the wheel

FIG 78. Type of Wooden Artillery Wheel constructed with tongue-and-groove joints between the spoke wedges, ensuring greater strength and rigidity.

"gather," which is to say, follow the track. A moderate dish contributes to the end of bringing the tire square to the ground, while at the same time enabling the wheel to rotate without undue wear at the axle.

2. Another constructional advantage involved in the dishing of wooden wheels relates to the method of shrinking on the iron tire. As is known, the tire is first forged to as nearly the required diameter as possible, after which it is heated, so as to

cause it to enlarge its diameter, and in this state placed about the rim of the wheel. When once more cooled it fits tightly. As frequently happens, however, a tire is made somewhat too small for a wheel, which involves that, in the act of shrinking, it will either force the wheel into a polygonal shape or crush one or more of the spokes. By giving the wheel a dish, the shrinkage of the tires merely increases the inclination of the cone from base to apex, the spring of the spokes being quite immaterial, all suffering to about the same extent.

**Dished Wheels for Automobiles.**—Ever since the motor carriage industry achieved anything like large proportions, the possibility of using dished wheels has been actively discussed. The numerous advantages to be attained have tempted several inventors to devise some suitable means for using them at least on heavy wagons. Among these may be mentioned the De Dion jointed axle and the Daimler driving differential, both of which have already been described. When we consider, however, that a large part of the real efficiency of a dished wheel lies in an inclination of its axle, it is easy to see that its application to an automobile presents serious constructional problems. With a divided rear axle shaft of the usual description, it would be impracticable to incline the axles from the differential, except by some form of universal or slip-joint, as in the De Dion carriages. Consequently, until the patents on this device expire, the differential gear cannot be attached above the springs, as is desirable, for many reasons, nor can dished wheels be used.

**The Use of Wood Wheels.**—Charles E. Duryea enumerates the following advantages to be found in using wooden wheels:

1. The construction, proportions and strength suitable for given requirements have been carefully determined by years of practical experience.

2. Being practically one piece, they do not deteriorate by usage in bad weather and are readily cleaned.

3. If broken, they may be anywhere repaired, all the parts being easily obtainable.

4. They will often give good service even in a bady damaged condition.

5. Experience has shown that they are far more elastic than wire wheels.

6. In wire wheels any attempt to make the hub of proper length to give spread to the spokes under strain results in a clumsy appearance.

7. If the spokes are proportionately strengthened the wire wheel becomes heavier than the wood wheel.

8. The greater number of spokes in a wire wheel, and their proximity at the hub, where dirt and moisture are collected, prevents easy cleaning and promotes rust.

In regard to elasticity Mr. Duryea says:

> "As a matter of fact, the wood wheel is far more elastic than the steel wheel, as may be readily seen by watching a light buggy drive over car tracks or rough payments. The rims of the wheels vibrate sideways, sometimes as much as two inches, without damage to the wheel or axle, on which account fewer broken axles will be had when wood wheels are used instead of wire ones. While it is true that the pneumatic tire practically removes the necessity of an elastic wheel, there is no need of refusing to accept a valuable feature."

**Dimensions of Automobile Wheels.**—As a general proposition we may assert that the larger the wheel the smaller the shocks experienced in passing over inequalities in the road-bed, and the smaller the buffing qualities required in the tires. Thus it is that a wheel five feet in diameter will sink only one-half inch in a rut one foot wide, while a thirty-inch wheel will sink nearly three times as deep, with the result that the resiliency of its tires must be enormously larger, in order to compensate the greater shock experienced. The larger wheel also rises less quickly over obstructions. These are considerations of great importance in motor vehicles, in which any device for the reduction of vibration

and concussion is desirable. Furthermore, when a wheel is properly tired, the road resistance to its steady and even rotation is decreased as the square of the increase in its diameter, such a wheel of sixty inches diameter decreasing the resistance in a ratio of between 50 per cent. and 70 per cent., as compared with a wheel of thirty inches diameter.

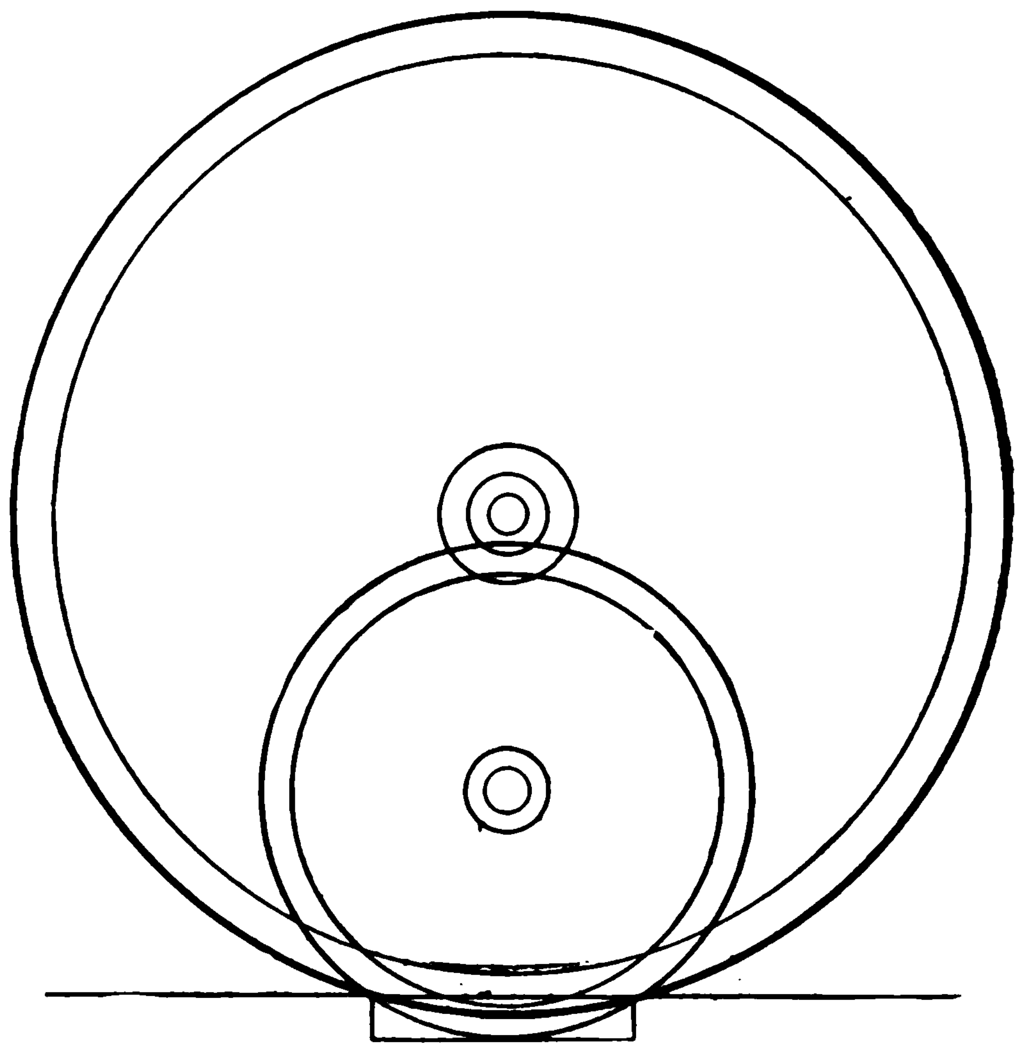


FIG. 79.—Diagram showing the relative drop into a road rut between a small carriage wheel and one twice its diameter.

There are, however, other methods for neutralizing the shocks on rough roads. The end of obtaining a low and easy-running rig may be achieved quite as well by increasing the width of the vehicle, the length of the springs and the size of the tires, as by adding to the height above the ground. Also, the broad tire is superior to the narrow one in the very same particular that it will not sink so quickly into mud and sand, and, by its greater buffing properties, neutralizes the concussion otherwise experienced with small wheels. These and other similar considerations have largely determined the prevalent practice of using wheels of moderate diameter for automobiles.

On the other hand, as many claim, the small wheel is destructive to tires in inverse ratio to its diameter and an increase in proportion would involve a corresponding economy in rubber. In this point, as in others, experiment is a better guide than theory, and if, as some claim, heavy high-speed vehicles can be constructed with wheels of large diameter, they have only to build their vehicle and try it out.

Arguing that it is a distinct advantage to enlarge the diameter of motor carriage wheels for the purposes of obtaining an offset to the concussions experienced on rough roads, to obtain higher speed within certain limits, and to secure greater durability for the tires, particularly when solid rubber tires are used, a prominent American tire-maker writes as follows:

"To prevent traveling on the rim a tire should bind the whole surface of the rim. The higher the wheel the more adhesive surface there is for the tire. When the tire is bound in by lugs the natural kneading and straining of it between the lugs will in time either shear off the lugs or loosen them. Another reason why a large wheel is to be preferred from a tire-maker's point of view is that a large wheel does not turn round so many times in a given distance, and consequently does not wear the tire so fast. If a tire travels very fast under a heavy load the kneading of it causes heating and cracking, which are intensified on the small wheel. Our experience has proved that a large wheel greatly reduces the above difficultes."

**Troubles with Large Wheels.**—As against theoretical advantages involved in the use of large wheels, there are numerous objections of equal, if not greater, importance. Among these may be mentioned the fact that, the larger the wheel the greater must be its proportional strength and weight of construction, in order to neutralize the ill effects of torsional motor effort, and disproportionate road resistance. Indeed, a moment's reflection will show that a wheel of sixty-inch diameter, built on the same dimensions of hub, spokes and felloes, as a wheel of thirty-inch diameter, will possess considerably more than twice the liability to strain and breakage from the causes above named. If we may assert that such increased liability, as compared with the increase of diameter is on a ratio of three to two, it is obvious that a wheel

of sixty-inch diameter must be very nearly three times as heavily and strongly built as a wheel of thirty-inch diameter, in order to insure its durability. We may readily judge, then, at about what point of increased diameter a light pleasure carriage would be equipped with cart wheels. This is only one of the numerous difficulties involved in attempting to use large wheels with a modern high-speed motor.

# CHAPTER NINE.

## SOLID RUBBER TIRES; THEIR THEORY AND CONSTRUCTION.

**The Question of Tires.**—All automobiles and cycles, and a large number of horse-drawn vehicles, use rubber tires. The object is twofold:

1. To secure a desirable spring effect.
2. To obtain the requisite adhesion to the road.

While, with properly constructed springs, the first result may be achieved with steel tires, the second is almost impracticable when the power is applied direct to the wheel. Thus, if a light automobile be equipped with steel tires, the wheels will not drive on an imperfectly resistant road-bed, unless most of the load be placed over the rear axle, which, when it is too great in proportion, involves the disadvantage that the steering will be unreliable, the forward wheels tending to skid, instead of turning the vehicle in a positive manner. It is not always practicable to remedy this difficulty, either by strewing sand in front of the wheels or by applying power to all of them. An attempt to produce adhesion by constructing tires with teeth or corrugations, or by giving them extra breadth, would increase the weight for only temporary advantage. The simplest and readiest resort is found in the use of rubber tires.

**The Reduction of Vibration.**—On the point of reduced vibration in a vehicle, as it is related to the kind of tires used, W. Worby Beaumont says:

"It must also be remembered that the greater comfort of the rider is due to lessened severity of vibration and shock, and this is a relief in which everything above the tires participates. Now, this means a reduction in the wear and tear of every part of the car and motor which can easily be underestimated. The experience of the London cab-owners, whose records of every cost are carefully kept, is a proof of this; and they find that rubber-tired wheels suffer very much less than the iron-tired; every part that

could be loosened or broken by constant severe weather or hard vibration remains tight very much longer; the breakage of lamp brackets, hangers and other parts does not occur, and that even the varnish, which being hard and breakable, lasts a great deal longer. The same immunity of the high-speed car is obtained by pneumatics, as compared with solids, and its value is greater in proportion to the greater value of the vehicle."

**The Working Unit.**—The situation to be met in providing proper supports for a motor carriage may be more readily understood by considering the vehicle and the roadway as the two components of a working unit, precisely like two mutually-moving parts of any machine. In both cases these parts must be calculated and arranged to move, the one upon the other, with the least possible friction and wear. An English authority on motor vans writes as follows:

"The prime fact with which engineers have to deal is that the success or failure of any design mainly depends on the nature of the road on which the van is to be worked. The V-slides of a planing machine are integral parts of the whole. The permanent way of a railroad and the rolling stock constitute together one complete machine. In just the same way the King's highway must be regarded as an integral part of all and every combination of mechanical appliances by which transport is affected on the road. In one word, if we attempt to dissever the road from the van, we shall fail to accomplish anything. Two or three years ago, the maker of a steam van told us that he was surprised to find how little power was required to work his van. He had been running it on wood-paved streets. A week or two later on he was very much more surprised to find that on fairly good macadam after rain he could do next to nothing with the same van. In preparing the designs for any van, the quality of the roads must not for a moment be forgotten; and it will not do to estimate the character of the road by anything but its worst bits. A length of a few yards of soft, sandy bottom on an otherwise good road will certainly bring a van which may have being doing well to grief. Curiously enough we have found this apparently obvious circumstance constantly overlooked. This is not all, however. A road may be level, hard, and of little resistance to traction, and yet be very destructive to mechanism. This type of road is rough and "knobby;" it will shake a vehicle to pieces, and the mischief done by such road augments in a most painfully rapid ratio with the pace of the vehicle. Jarring and tremor are as effectual as direct violence in injuring an auto. Scores of examples of this might be cited. One will suffice. In a motor van a long horizontal rod was used to couple the steering gear to the

leading wheels. The rod was broken solely by vibration. It was replaced by a much heavier and stronger bar. That was broken in much the same way, and finally guides had to be fitted to steady the rod and prevent it shaking."

**Analogies for a Buffing Support.**—In automobile building the principal concern is for the vehicle, which must be constructed so as to endure the most unfavorable conditions of road-

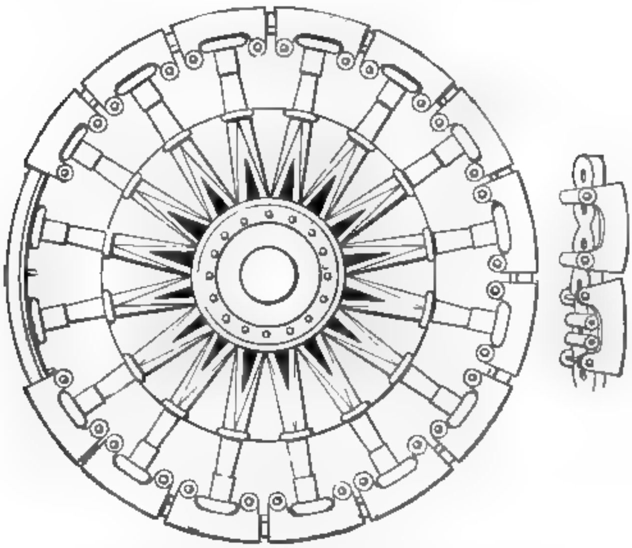


FIG. 80.—Wheel of the "Lifu" Steam Truck, showing a solid rubber cushion tire secured in position and protected by metal shoes around the rim. Although the attachment is so rigid as to prevent creeping, a very effective spring effect is obtained by combination of the cushion tire and shoes It is effective for heavy service, which would soon destroy an ordinary tire.

bed. The effect on the road is quite secondary. In the construction of railroad locomotives, on the other hand, both components of the working unit, the vehicle and the tramway, must be considered: both must be constructed to interact with a minimal wear and damage. In this connection we may quote Matthias N. Forney, a well-known locomotive authority. In speaking of springs, which in locomotives perform some of the functions delegated to flexible tires in automobiles, he says:

"A light blow with a hammer on a pane of glass is sufficient to shatter it. If, however, on a pane of glass is laid some elastic substance, such as india-rubber, and we strike on that, the force of the blow or the weight of the hammer must be considerably increased before producing the above named effect. If the locomotive boiler is put in place of the hammer, the springs in place of the india-rubber, and the rails in place of the glass, the comparison will agree with the case above."

While in automobiles the effect on the road-bed is inconsiderable, the light and delicately-geared machinery must be protected from damage—the anvil must be shod. Whence it follows that, in the absence of anything like the steel rail surface of a railroad, utility of tires increases directly with their yielding and shape restoring properties. The more readily these functions are exercised, the smaller the wear on all the elements composing the working unit. Furthermore, the necessity in this particular becomes greater in proportion to the weight and contemplated speed capacity of the vehicle, and, beyond the point where pneumatic tires are practical, must be compensated by more efficient springs and lower rates of travel.

**Rubber Tires for Automobiles.**—There are two varieties of rubber tire in use for every kind of vehicle except cycles: the solid tire and the pneumatic, or inflatable tire. As is generally known, the pneumatic tire was first devised in order to furnish the needed resiliency in bicycles, and for the same purpose it has been found useful in automobiles. It is also superior in point of tractive qualites, "taking hold" of the road-bed far more effectively than the best solid. It has, however, one notable disadvantage, the constant liability to puncture, with the consequent danger of being rendered useless. In order to remedy this defect, inventors and manufacturers have introduced such features as thickening the tread of the tire, increasing its resistance to puncture by inserting layers of tough fabric in the rubber walls, and, latterly, by shoeing the entire tread surface with leather.

At the present time pneumatic tires are almost universally used on automobiles, solids being found only on electric vehicles, in-

tended for use on city streets, or on heavy slow-speed trucks and vans. It is not too much to say, however, that the finality has not yet been reached, and that there are still reputable authorities who hold that, with perfected spring attachments, the solid tire may yet see a wider sphere of usefulness.

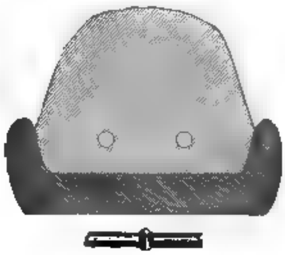


Fig. 81.

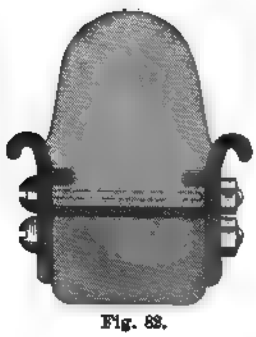


Fig. 82.

Fig. 83.

FIGS. 81, 82 and 83.—Three varieties of Solid Rubber Tire, showing shape and methods of attaching on the rims. Fig. 81 shows a broad tire, which is attached by forcing over the edges of the channel-shaped rim, to which it is vulcanized, and also secured by endless wires, welded, as shown. Fig. 82 shows a tire secured by bolts through the base, also by annular lugs on the rim sides fitting into channels. Fig. 83 shows an attachment made by connecting at the base by a peripheral T-piece, also by bolts securing sides of channel-shaped rim. All three varieties show rim channels, so shaped as to allow of considerable distortion, laterly, under load.

W. Worby Beaumont writes:

"For high-speed running with comfort over street crossings and level railway crossings, the expensive pneumatic is necessary, but it is a high price to pay for this luxury, and it will only be paid by the few who will pay anything for speed After a while, when automobile travel settles down to the moderate speeds of the majority, and to the requirements of business, the better forms of solid or nearly solid tire, in which a com

paratively small amount of internal movement of the rubber takes place, will probably be most used. A hard pneumatic tire is superior to this for ease at the bad places in roads and over crossings, but greater strength of material suitable for the purpose than is yet available is required to meet all the conditions."

As to the durability of solid tires, under constant use, he says:

"With regard to solid tires, the experience of the London hansom cabs is of much interest. A pair of 1⅝ or 1¾ inch tires will last from a little over six months to, at most, nine months. The most rapid wear is on those cabs which have the best and fastest horses, if we except those cabs that have constantly to run in districts where the road surfaces are destroyed by the prevalence of tramways. * * * * * If thirty miles per day for the hansom driven by men who are, as most are, allowed two horses per day, and assuming 300 days per year, then a year's mileage would be 9,000. They run, however, not more than eight months at best before tire renewal, so that the mileage is not probably more than about 5,500 to 6,000. * * * The mileage of the tires on the four-wheel cabs is much greater, as would be expected, from the smaller weight each wheel carries and the lower speed. The miles traveled per month will also be less."

**Structural Requirements in Solid Tires.**—The shape and methods of attaching solid tires to the wheel rims must both be determined with reference to the source and pull of the strains likely to affect them. The weight of the vehicle is nearly the greatest source of wear, but even this consideration is closely rivaled by the torsional strain from the engine and in braking, particularly in view of the almost universal use of comparatively small wheels. Indeed, no part of the wheel could suffer greater strain than the tire from the condition last mentioned. In view of the properties of rubber, it may be readily seen that increasing the thickness of the solid tire, in proportion to the increased weight of the vehicle, will largely neutralize the destructive effects due to every cause involved in the structure of the running gear and its load. By this means is obtained a greater width of tread, with a probably smaller total abrasion of the surface from contact with the road-bed, and a greater opportunity for distributing and neutralizing the harmful strains.

The tendency in solid tires is that cuts, due to stones or other sharp obstacles, tend to spread to the centre of the tire across the tread. This is due to the quality of the strains transmitted from the wheels, as above noted, and in order to prevent this tendency from destroying the tire it is necessary to vary the shape. Accordingly, tires are made with bevel edges, rather than on square lines, and the profile is slightly rounded. This conformation, together with good width at the rim, is able to provide for absorbing much of the surplus vibration, while decreasing the ill effects due to the combined action of a heavy load and road resistance.

Fig 84.

Fig. 85.

FIGS. 84 and 85.—Two Models of the Swinehart Solid Clincher Tire, which derives a good degree of resiliency from its construction with beaded tread and concaved sides.

On the whole it greatly prolongs the life of the tire. The curved surface at the tread and the bevel edges, tending to flatten under the load, provide a sufficient width to ensure good adhesion and the other advantages belonging to a wide tire, while, at the same time, reducing to the minimum the tendency to spread tears and cuts, as above mentioned.

**The Present Situation on Solid Tires.**—In justice to the earnest efforts of numerous inventors to improve the types and efficiency of solid tires, it must be confessed that the situation has changed materially in the last few years. As shown in Figs. 81, 82 and 83 the prevailing types of tire to a very recent date had a section of approximate rounded triangular shape, which, firmly secured at the sides, all around the rim, possessed a min-

imum degree of distortability and elasticity. That such tires were "unresilient" and liable to tear is hardly remarkable. Furthermore, that they were subject to serious cutting by stones and other sharp objects seems no less than inevitable. Recent improved tires, departing entirely from such models, have attained a good degree of resiliency and of immunity from such accidents by devices like perforating and concaving the sides of the tire all around above the rim.

The Swinehart solid clincher, shown in Figs. 84 and 85, embodies the excellent features of

1. A Heavily Beaded Tread.
2. Deeply Concaved Sides.
3. Superior Elasticity in the Rubber.

The beaded tread and concaved sides permit of considerable compression under load and the ability of absorbing heavy jolts without serious vibration. As will be readily understood, the construction seems to go far to warranting these claims. The manufacturers confidently assert that their tires are equal to any kind of service up to 35 miles per hour, but claim high efficiency at speeds above 40 miles under a heavy touring car. High averages of durability, traction, hill-climbing and power economy have also been attained, with performances equal, if not superior, to pneumatics. For ordinary speeds the serviceability of this type of solid tires cannot be questioned.

# CHAPTER TEN.

## THE CONSTRUCTION AND TYPES OF PNEUMATIC TIRES.

**Advantages of Pneumatic Tires.**—The most valuable quality of the pneumatic tire is its resiliency, or the ability to bounce in the act of regaining its normal shape after encountering an obstacle in the road. On encountering a stone, for example, it will yield to a certain extent, absorbing or "swallowing it up," at the same time exerting a pressure sufficient to restore its normal shape. This quality begets two advantages for easy driving:

1. It does away with much of the lifting up of the wheel in passing over obstacles, which is otherwise inevitable.

2. It enables the tire to obtain a better grip on the road-bed.

Commensurate advantages are also derived from this cushioning quality in colliding with obstacles to one side or other of the tread, whence the total pressure exerted through the spokes is greatly reduced and such obstructions exert only a fraction of their usual power to retard the easy and steady operation of the motor and steering gear. In both cases, also, a large part of the shocks and vibrations, usually transmitted direct to the springs, are completely absorbed. No solid tires could furnish anything like such advantages in operation; the usual result, even with the most flexible springs, being that the motor is much shaken or damaged, or its action largely impaired. This is particularly true of the use of solid tires on electric vehicles, the damage resulting, both in point of efficiency and durability, having been estimated by several authorities as high as 30 per cent.

**Pneumatic Tires, Speed and Power.**—A prominent tire expert furnishes the following data on pneumatic tires, based on experiments:

"I have made tests with 2½ and 3 inch solid rubber tires on automobiles ranging from 16 to 24 horse-power, and on carriages weighing 1 ton to 1½ tons, and have ascertained that both of these automobiles could run safely on a good road at a maximum speed of 42 kilometers, 25 1-10 miles, an hour. When the driver attempted to go beyond this speed (always on a perfect road) the motor was subjected to such fearful vibrations its complete demolition was threatened. Under the same conditions of horse-power, weights and tires, but on what is considered a bad road, it was impossible to attain more than 15 miles an hour. The same autos, with pneumatic tires, made 60 and 70 miles an hour on an average road."

While the average automobilist never contemplates such high speeds as 60 or 70 miles per hour, it is only fair to remark that speed, combined with general road qualities, furnishes the test conditions for the jar-absorbing, vibration-neutralizing, and adhesion-increasing properties of pneumatic tires. Furthermore, as the result of numerous experiments, it may be correct to assert that a tire, best fitted to endure test conditions as to speed, is also within certain limits the most suitable type and make to travel under heavy loads, with a minimum of traction effort. For, as most figures seem to indicate, the decrease of traction effort is in ratio with the elasticity of the vehicle's support.

It must not be forgotten that such tests as these were made exclusively with high-speed cars, which, as is generally admitted even at the present day, cannot operate satisfactorily without pneumatics; again, that the tires used were of the ordinary round or conical tread pattern which permit of very little distortion under load and very slight resiliency.

Within recent years several types of solid and semi-solid or cushion tires have been introduced, which seem to furnish sufficient resiliency and traction efficiency for ordinary service. Among these the most noteworthy is the Swinehart tire. As shown in the figure page 105, its features are a corrugated tread and concaved sides. The makers claim for their tires superiority over pneumatics on any except the heaviest high-speed cars, not only in point of traction and speeding, but also in hill-climbing.

**Single and Double-Tube Tires.**—There are two varieties of

pneumatic tire, the single and the double tube. The double-tube tire was first introduced, and in all its various forms consists of an inner, or air tube, made of thin and elastic india-rubber, enclosed in the outer or case tube, built up of strong fabric and a tougher and denser kind of rubber. The case tube is split on its inner face, which bears against the periphery of the wheel, in order to allow the air tube to be readily removed at any time for repair or replacement. The single-tube tire was devised as an improvement, whereby the layers of thread and tough rubber are formed upon and around the delicate air tube, making the two tubes really one. The double-tube tire is most commonly used on automobiles, being preferred on account of several advantages which will be presently mentioned.

**Fabric Tires.**—Pneumatic tires of both varieties were formerly built up with layers of some tough woven fabric, such as canvas, in which the warp and filler are of the same size, as in ordinary duck and other cloth. This kind of fabric, known as "square woven," has many objectionable features, particularly when the manufacturing process is not most carefully conducted. Unless the most improved methods are employed, the rubber, during vulcanization under heat, develops wrinkles in the canvas fabric, which causes unequal strains on the various plies, or layers, and constitutes the defect known as "buckling." Even without this defect, a woven fabric tire is liable to develop internal chafing between the contiguous threads of each layer, which results in heating, to the eventual deterioration of the entire structure.

**Thread Tires.**—Experience has proven that strength and immunity from heating demand:

1. That there shall be sufficient clearance between the contiguous threads of a tire fabric to allow a large and firm attachment between the rubber layers above and below each ply.

2. That the possibility of direct contact between individual threads shall be prevented, thus removing the occasion for chafing and heating.

In order to accomplish these results, the so-called thread fabric is used for both varieties of tire.

**Single-Tube Thread Tires.**—The methods of manufacturing single-tube thread tires is thus explained by Pardon W. Tillinghast, their original inventor:

"A fabric must be employed in which there is no starting point of separation between the fabric and rubber, and one that does not have a substantially smooth surface, or a surface that is continuous in the same plane. The attaching surface of the fabric presented for union with the rubber must be greatly in excess of that furnished by the fabrics in use at the present time. A plurality of plies may be used, some of the plies having

Fig. 86.

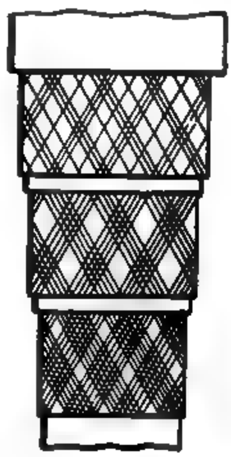


Fig. 87.

FIGS. 86 and 87.—The construction of two types of Tillinghast Single-Tube Tires. Fig. 86, shows the formation of the fabric into a succession of loops. Fig. 87 shows the open thread fabric tire in which separate threads are wound, in the manner indicated, over each successive rubber layer or tube.

a more open weave or construction than other plies, and all plies separated by rubber, which will give in effect a single tube or mass of rubber, having fibrous threads extending throughout the mass to prevent bursting, and binding the whole structure into a substantially indestructible body.

"Another means of accomplishing the same end consists essentially of employing a fabric which, when built into a tire, will have the same effect that a bath towel would if it was inclosed and imbedded in the rubber, with the threads sufficiently strong to withstand the inclosed air pressure,

the little loops or fibres extending away from the general plane of the main fabric into the surrounding rubber and being vulcanized therein, furnishing an increased surface for union with the rubber; the general surface line of the fabric in each construction is to be broken so that it is not continuous in the same plane, and there is no starting point of separation between the fabric and rubber."

Accompanying figures illustrate the construction of two recent types of tire. One of them is built up with a number of strands of thread running longitudinally on the tube and wound spirally with other threads which hold them securely under inflation. The spiral windings are then pushed along the length of the tube, so as to reduce the distance between the windings

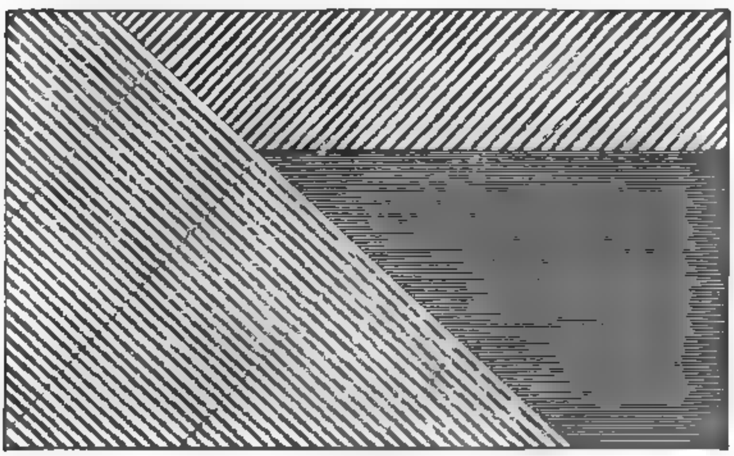


FIG. 88.—Diagram of the successive thread layers in the case-tube of a double-tube thread tire.

from one-quarter inch to less than one-eighth inch, with the result that the intermediate sections of the longitudinal threads are pushed up into series of loops, thus forming stronger attachments for the fabric, when held in the material of the rubber wall built up over this layer of threads. Tillinghast's other method of strengthening the fabric against any cause tending to burst or tear the walls, involves several layers of plies or layers of threads wound on in two diagonal directions, each one being in a more open construction than the last, the closest being on the inmost ply.

**Manufacture of Thread Tires.**—In the construction of thread fabric double-tube tires, each case tube is built up of plies of strong threads running parallel, and unwoven, except for light cross threads at intervals to hold the main threads in position. Each ply is vulcanized, above and below, to rubber layers, which are applied by heat, under pressure, causing the rubber to be forced between the threads, like plaster between the lathes of a wall, and entirely surrounding them. The entire body of the case

Fig. 89.

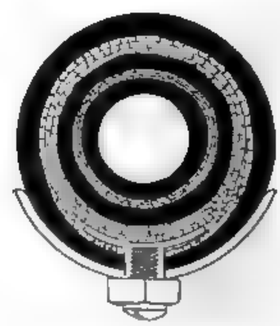


Fig. 90.

FIGS. 89 and 90.—Sections of double and single-tube pneumatic tires, showing shapes of rims and methods of fastening.

tube is thus in practically one piece, made extra strong and resistant by arranging the threads of each separate ply at right angles with those of the one above or below it. Each thread being thus thoroughly imbedded in rubber, those in consecutive layers cannot come into contact. There is consequently no abrasion or heating, and the threads act, both separately and together, to strengthen the structure in every direction of stress. The end of strength is achieved by using several plies of thread, all inserted under even tension, which cannot be done with square-woven fabric. A further advantage claimed by the advocates of thread fabric is that the rubber more readily and more completely penetrates the interstices between the threads than is possible with the square weave.

**Attachments for Tires.**—Where single-tube tires are used on automobile wheels the attachment is made by bolts passing through the rim and secured by wing nuts on the inside surface. Each bolt is of one piece with a chaplet head or plate imbedded in the fabric. While such attachment is sufficiently strong under ordinary conditions, particularly when the tire is thoroughly inflated, it is desirable to spread hard cement in the rim channel, in order to prevent the accumulation of dust and sand, which are always seriously destructive to the tire.

Single-tube tires, attached as described, are very well suited for light vehicles and low speeds, but not at all for heavy, high-speed service. The principal reason is that the attachment, although probably the best possible under the necessary conditions of service, does not altogether neutralize the tendency of the slingle tube to creep, nor prevent rolling off the rim, should the lugs become loosened or broken. Apart from the dangers of puncture, rim-cutting, etc., shared by both varieties of tire, the single tube, as at present designed, exhibits the tendency to creep to such an extent that the greatest strain is always brought to bear upon the lugs. Being of rounded contour, it is also liable to roll on any attempt to make a sharp corner at high speeds, the attachments at the base often proving insufficient to resist the sidewise stress, and being repeatedly loosened. Thus, although embodying the great advantage of being more easily treated for puncture, the single-tube is practically inferior to the double-tube tire.

**Comparison of Tires.**—As regards the relative merits of the two varieties of pneumatic tire, we may profitably quote Charles E. Duryea. He states his conclusions as follows:

"The ordinary round tire lying in an arc-shaped rim, as is the common method, cannot utilize its side walls properly when meeting an obstacle, since it is flattened toward the rim and caused to bend at the side abruptly at two places; being bent outward over the edge of the rim and inward at its widest point. The outward bend, together with dirt which may get between tire and rim, tends to chafe the tire on the edge of the rim, a phenomenon commonly known as rim cutting. The other bend cannot

stretch the outer layers of fabric, so it must compress the inner fabric and inner rubber, which compression rapidly causes a crack, weakening the tire from the inside, with the result that in a short while the tire begins to swell along the sides and finally bursts. Any rim, therefore, which will hold the tire at the bottom only, and yet preserve it from rolling sidewise on the rim, is conducive to long life of tire, for it leaves the side walls free from short bends and increases the depth of the tire, which increases its beneficial results as well."

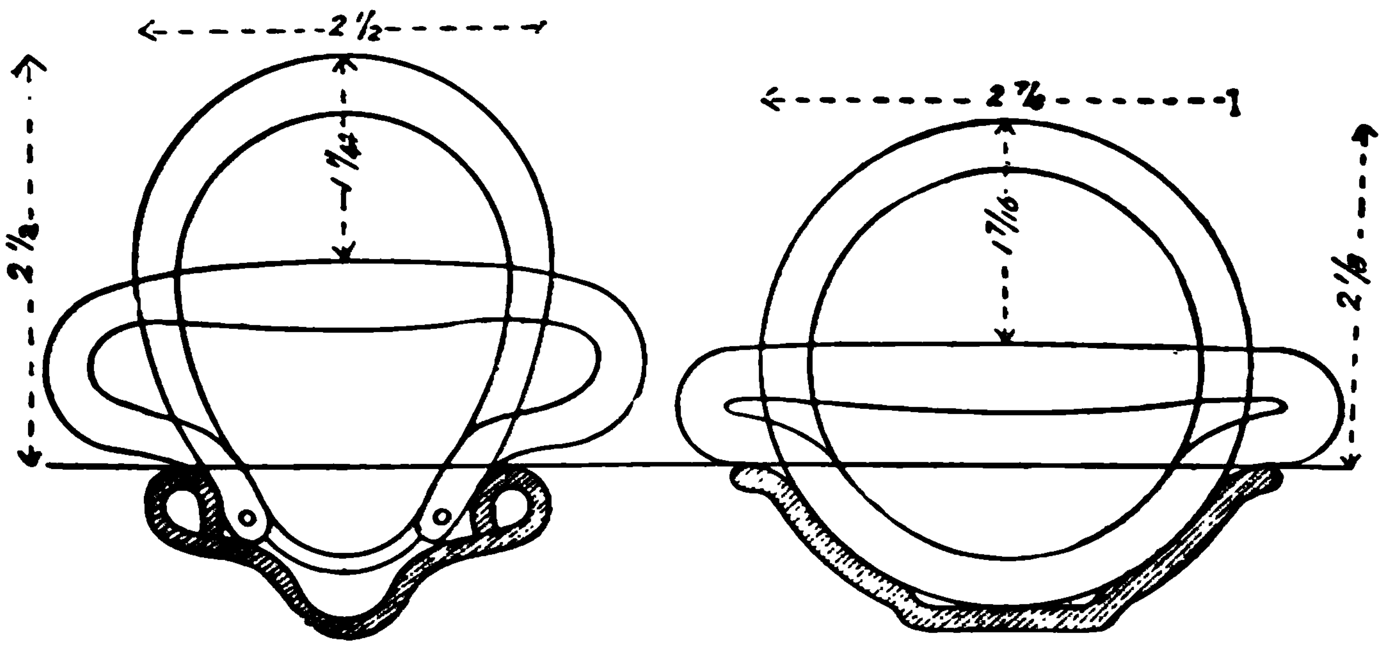



FIG. 91.—Diagram illustrating the relative degree of flattening consequent on deflating a double-tube pneumatic, mechanically secured to base, and a cemented single-tube pneumatic, through one-half diameter above edges of rim. Note the sharp corners of the single tube.

An accompanying figure of a mechanically fastened double-tube tire and of a single-tube cemented tire with arc-shaped rim, shows their shapes when inflated and when deflated to one-half their diameter; demonstrating that since a double-tube tire may be compressed further than a single tube, a small tire of the former variety is as efficient in smoothing the road as a larger one of the latter variety. A proportionate deflation of the two shows a further advantage, in that the walls of a double-tube tire are bent much less for a given compression than those of a single tube, and are forced against the edges of the rim with much less compression. The single-tube tire does not flatten out so widely in proportion to its diameter as does the double tube, which fact is of importance, because added width means added supporting surface, tending to resist further compression as it increases.

Duryea concludes, therefore, that:

> "The best automobile tire is the one mechanically fastened so as to relieve the fabric from the strain of holding the tire in position. Its fabric must be as strong as possible, because of the heavy service which means a long fibre closely-woven canvas of the greatest possible strength and the fewest necessary thicknesses which arrangement is less liable to puncture or tear than any thread fabric and is yet as flexible as the necessary strength will permit. Being mechanically fastened, the fabric need not be stretched in the direction of the length of the tire which increases the resilience and lessens the strain and liability of rupture in passing over obstructions."

As may be readily understood, a further advantage gained by using a double-tube tire, mechanically fastened at the base, is that the sidewise strains encountered in turning corners, are not so liable to cause rolling off the rim. In bicycles this danger is largely averted by the rake, or inclination, taken by the wheels in turning corners, which maintains the entire wheel-structure, including the tire, in one plane. But in automobiles this rake cannot be obtained except with the front or steer wheels, the result being that the strain brought upon a tire in turning corners at high speed is enormous. A tire standing high above the rim and rigidly attached at the base is capable of a very considerable sidewise deformation without particularly great danger of rupture or other accident. Howbeit, if the inflation be insufficient, such side strains are very liable to loosen the fastenings, particularly when clamps are used.

**Advantages of Double Tubes.**—Double-tube tires are practically immune from creeping, on account of the security of their attachment to the wheel rim. They will not roll off, like single tubes, although the attempt to turn sharp corners at high speed strains the fabric excessively, and at times may result in rupture. There are two general methods of attachment: by clinches and by side-flange. In both there is a secure joint between the tire base and the rim at every point around the periphery of the wheel.

**Clincher Tires.**—A very large proportion of double-tube tires are of the clincher type, being constructed with rubber and fabric flanges on either side of the case tube, which fit snugly into channels formed by inturning the edges of the rim. These chan-

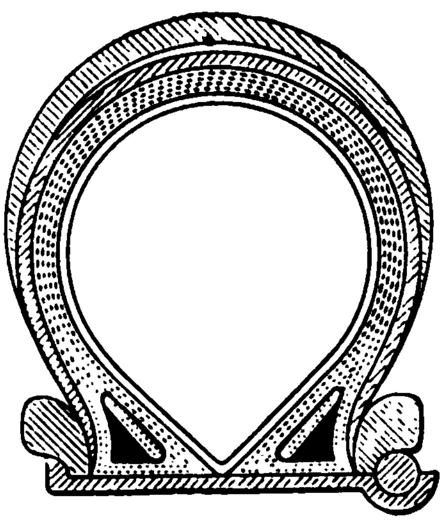


Fig. 92.

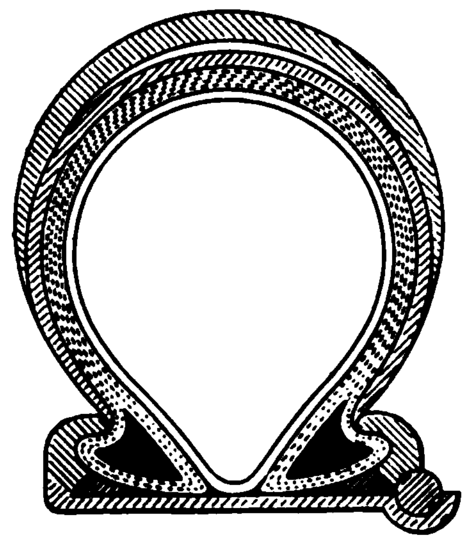


Fig. 93.

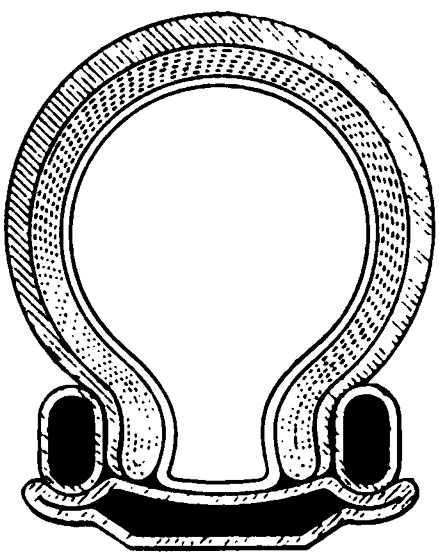


Fig. 94.

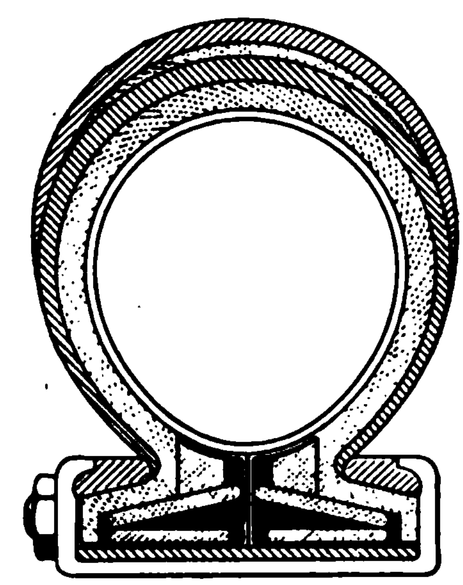


Fig. 95.

FIGS. 92, 93, 94 and 95.—Four Forms of Double-Tube Pneumatic Tire, showing methods of securing to the rims. Fig. 92, the Goodyear Detachable Side-Flange Tire, with reversible side-rings; Fig. 93, the Goodyear Clincher with side-rings reversed; Fig. 94, the Dunlop Tire, showing tubular side-rings; Fig. 95, the Fisk Tire, showing bottom flanges and retaining rings held to rim by clips and nuts.

nels are the clinches. In removing the case tube it is necessary to insert a flat tool between it and the rim and pry them apart. This operation is tedious and also involves very great strain on the fabric. A careless hand may also cut or bruise the air tube, particularly when it is not protected by a flap.

**Side-Flange Tires.**—The side-flange tire is gradually supplanting the clincher in very many quarters, embodying, as it does, the advantage of being readily removable, without strain or injury to the fabric or rubber. The original patterns of this variety of tire were held upon the flat rim between two annular plates or flanges, bolted through the felloe. The Goodyear tire, probably the first of its type, was further enforced by strands of braided wire at the base on either side of the opening of the case tube. Its later forms have the wires, but are retained on the rim by two endless steel flange rings and an open steel locking ring, which holds the flanges in position.

**The Dunlop Tire.**—The latest Dunlop tire is logically in the side-flange class. Its special feature has always been two endless wire rings at either side of the base, which furnishes a sufficiently firm attachment to the rim. Former models of this tire were removable in the same manner as clinchers, by prying over the side of the rim channel. At present, however, removal is accomplished by loosening one of the tubular retaining rings, which is cut and securely held in place by screwing up a turnbuckle.

The Fisk tire has its case tube flanged at the base in somewhat the same fashion as a clincher, but is secured to the flat rim by two metal rings fitting snugly over the flanges and held tightly in place by lugs and bolts.

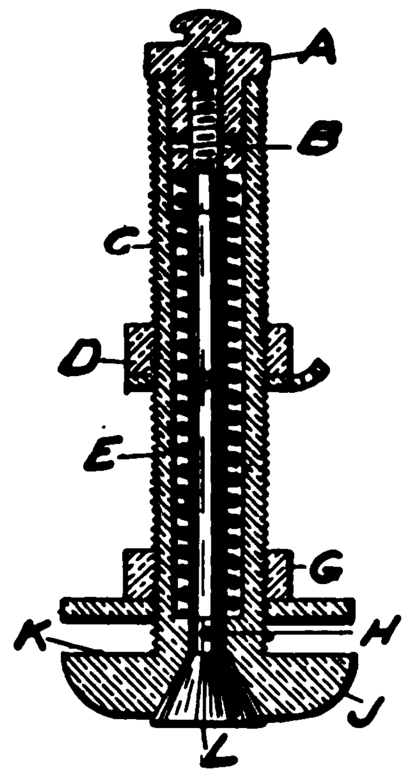



FIG. 96.

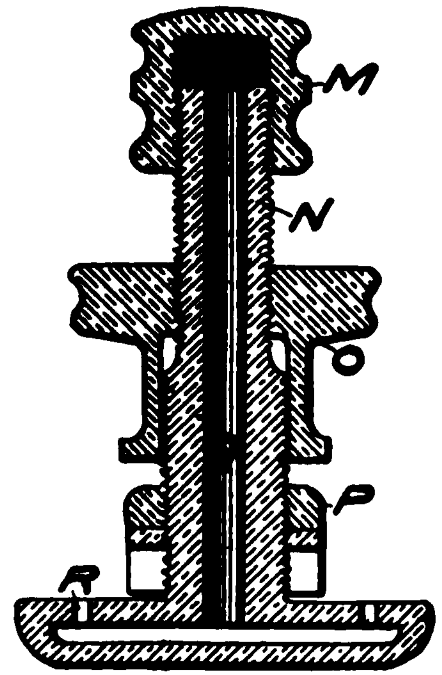



FIG. 97.

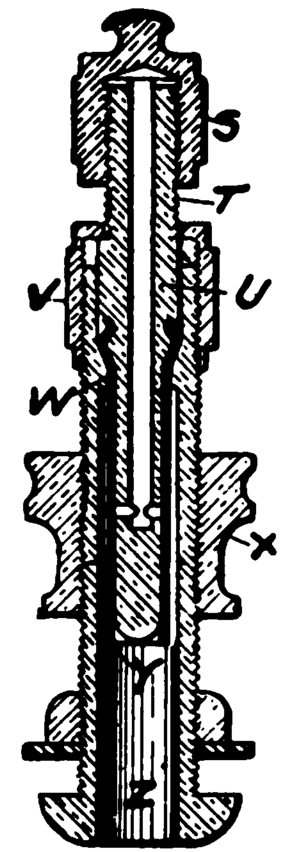



FIG. 98.

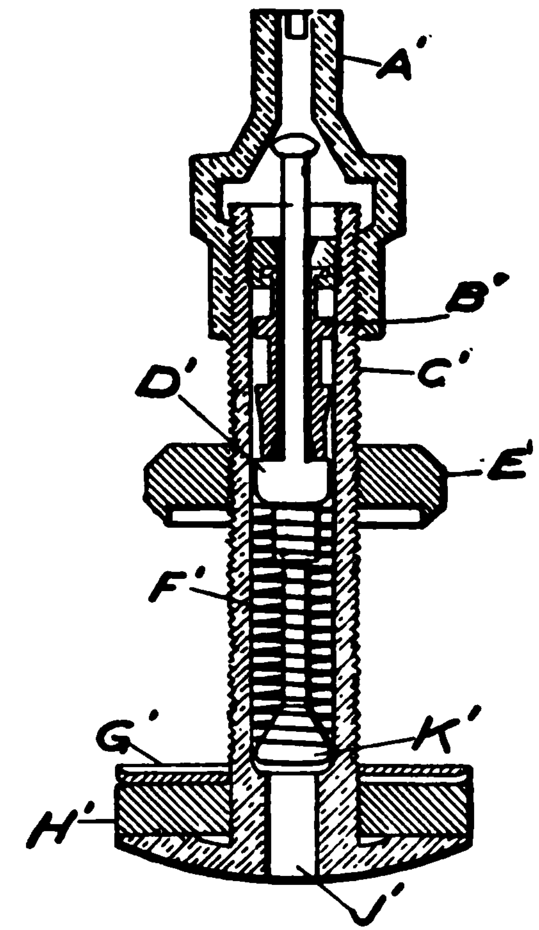



FIG. 99.

FIG. 96.—The Sangster Valve. A, removable screw-threaded cover; B, retaining nut, having notches at edge for passage of air; C, the valve tube; D, lock nut and washer for holding stem to the wheel rim; E, helical spring bearing on B and holding valve, L, in its seat; F, valve stem; G, washer holding valve stem to inner surface of rim; H, passages for admitting air into interior of tire; J, head on inner end of valve stem within tire; K, roughened face of J, making joint with the tire walls under air pressure; L, valve seated in J, and carried on the rod, F.

FIG. 97.—The Welch Valve. This is of the same general description as is used on several double-tube tires. M, the screw cap closing the valve tube; N, the valve tube; O, cap for gripping the wheel rim, on the inner side of which is the nut and washer, P, which presses the wall of the inner tube against the face of the head, R. When the inner tube is fully inflated the holes shown on the upper face of R are closed by pressure of the rubber walls against them.

FIG. 98.—The Wood Valve. S, the screw cap on the valve tube; T, end of the valve tube; U, tube for air from pump; Y, cap holding deflating valve, W, in the seat, loosed when tire is to be deflated; X, nut for holding valve stem to inside of rim; Y, a rubber tube around pipe. U, admitting air to tire when pressure is sufficient through ports at bottom of tube, U; Z, tube admitting air to interior of tire, also head and washer for attaching to inner tire tube.

FIG. 99.—The Schrader Valve. A' is the screw cap on the valve tube; B', the valve seat carried on the binding nut within the tube, C'; D', the valve; E', nut and washer for securing tire to the inner face of the wheel rim; F', spring holding the valve in its seat; G', H', washers bearing against outer face of wheel rim; J', head holding inner surface of tire tube; K', head at the lower end of the valve stem through grooves at the base of which the air enters the tire.

# CHAPTER ELEVEN.

## PNEUMATIC TIRE TROUBLES.

**Accidents to Pneumatic Tires.**—The serviceability of pneumatic tires depends upon a number of considerations, quite apart from any question of their merits as manufactured products. That a tire should embody the best available materials and workmanship must be evident on reflection, and any occasions for disablement arising from faults in these particulars need no lengthy consideration. If the case tube is poorly made, it will heat and crack. If the wall is too thin it will tear or cut. If the walls and tread are too thick and heavy the difficulty of bending under load is increased, sharp corners being formed and the fabric ruptured. If the attachment to the rim is insufficient the tire will creep.

**Causes of Excessive Wear in Tires.**—A tire may be injured in a number of ways, on account of faulty attachments, carelessness or hard service. Among the commonest forms of wear and tear are:

1. Creeping.
2. Puncture.
3. Rim-cutting.
4. Cracking of the walls.
5. Excessive wear on the walls or tread.
6. Chemical action.

**The Creeping of Tires.**—Creeping is found almost exclusively in single-tube tires. It is due to the fact that the weight of the vehicle, in process of travel, tends to centralize the pressure on the rubber walls, and cause the tire to bulge just forward of the point of contact with the ground. As may be readily recognized, a continued succession of such bulgings tends both to loosen the adhesion of the tire and the rim, and also to cause the tire to

push forward from the ground, and thus around the rim, in the effort to relieve and distribute the pressure. As a result, when inflation is insufficient, great strain and pull will be exerted where the valve is joined to the tire, and a rupture often follows at that point. Even were it possible to obviate the last-named accident, it is evident that the service of a tire, thus loosened by the creeping process is impaired. Moreover, it would inevitably roll sideways from the rim before it had been long in use. Also, if loose, it chafes at the rim and wears quickly. The only assurance against

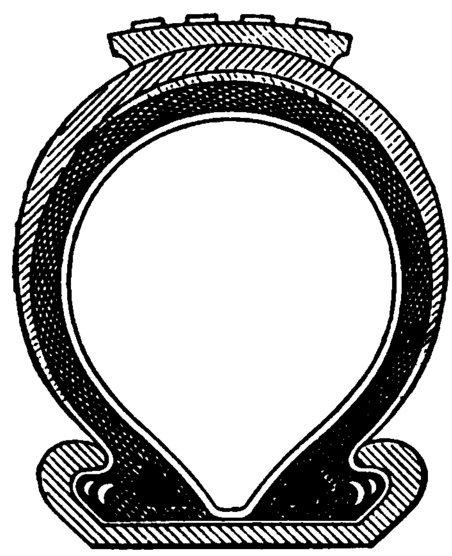


FIG. 100.—Leather-reinforced Pneumatic Tire, showing outside case of leather and spiked leather head.

creeping in a single-tube tire is found in reliable bolt and lug fastenings. Double-tube tires are immune from creeping on account of having complete peripheral attachments in clinches, side flanges, etc.

**Puncture of Tires.**—The accident known as puncture is such a piercing of the air tube as allows the air to escape and flatten the tire. It is generally caused by a sharp stone or a nail piercing the tread, in which event the air tube must be immediately repaired or else a new one substituted.

Among other possible causes of puncture are:

1. Nipping of the air tube by the tire removing lever; by the lug of the screw bolt; by the edge of the case tube.

2. Sand or other hard substances in the case tube.

Puncture is always an annoying accident, but with the later makes of tire, particularly those equipped with a leather tread, it happens less often than formerly.

**Rim-Cutting.**—Rim-cutting of pneumatic tires is a mishap arising generally from:

1. Sand or sharp particles lodged between the tire and the edges of the rim, which, particularly when the tire is partially deflated, cut through the outer layer of rubber to the fabric beneath.

2. Overloading, or compelling a tire to carry a weight greater than its dimensions warrant. This causes the tire to flatten, in spite of persistent extra inflating, and the result is nearly always shearing-off at the edges near the points where the flanges engage the clinches.

3. Defective or bent rims. Rims may be unsuitable for given makes of tire, because made for some other style. It is essential that the tire fit the rims perfectly, since, if the attachment is not tight, movement and chafing result, or stones and sand find lodgment; if it is too tight the pressure against the edges of the rim is excessive.

Loose or ill-fitting studs always allow some movement of the tire, and occasion cutting, at least in spots around the rim.

These mishaps occur less frequently at present than those due to bent or rusty rims, which work the same havoc as those that fit poorly. It is particularly necessary to keep the rim in perfect repair, to clean out all evidences of rust, and to remedy any bends or breaks at once.

4. Insufficient inflation is often a cause of cutting, even when the rims are in perfect repair. It is necessary to keep the tires pumped hard at all times. If cutting then results, it is the least possible evidence that the tires are too small for the load they are obliged to carry.

Carriage builders of the present day are able to calculate very accurately the endurance of a tire under a predetermined load. But if the vehicle is used for purposes not contemplated in the original design. it is evident that the tires will not endure. Excessive speeds, like overloading, will work destruction of the best tires. Indeed, both extremes amount to the same thing in the end.

No means has yet been devised to insure tires used on very high-speed machines.

5. Sharp curves or excessive side-slip tend to produce a side pressure that is concentrated at the rim, and, in proportion to the weight of the car, or the speed at which it is driven, are liable to result in cutting of the case tube. Side slipping or skidding is largely neutralized in cars with long wheel-base, but, even with this desirable structural feature, occasions may arise in which rim-cutting results from sudden turns. Once started, a weak point is developed that tends to increase the rent under all favorable circumstances.

**Cracking of the Walls.**—If a tire is well made any evidence of cracking of the case tube may safely be attributed to driving with insufficient inflation. As the result of a puncture or other mishap, all the air may be exhausted, causing the tire to be completely flattened under the weight of the vehicle. If this does not immediately produce cracking of the case tube, it is a rare good fortune. Long continued pressure of this kind will infallibly tear and destroy the fabric.

The remedy is, of course, to make such repairs as are possible at the time, or else to insert a new air tube. If no extra air tube is at hand, and repairs cannot be made conveniently, the best makeshift is to procure sufficient length of old rope to wind around the circumference of the wheel inside the case tube. This may be done by jacking up the wheel, in precisely the same fashion as if to insert a new air tube, and starting to wind the rope inside the case tube, entirely around the circumference of the wheel, until no more can be inserted. Care should be taken to leave sufficient clearance to insert the flange of the tube in the clinch. There will thus be afforded sufficient support to keep the tire from being flattened for more than half its diameter, thus probably saving the case tube.

**Excessive Wear on the Walls or Tread.**—Obviously a tire must undergo considerable wear in course of use. With the best possible roads and the highest grade of rubber a more or less

rapid deterioration is inevitable. For this, of course, there is no remedy. It is desirable, however, to avoid excessive wear whenever possible.

No tire should be used after the rubber at the tread or side walls has been worn down to the fabric. The result will be that the structure is weakened, offering a smaller resistence to puncture and tearing, also exposing the fibre to the destructive action of water and other corrodents, not to mention the more rapid wear due to abradents, sand, etc.

In case of extraordinary accidents that cut, wear or tear the walls, the case tube should be replaced immediately, in order to prevent an explosive rending of the air tube. This latter is a far more serious mishap than any mere puncture or even cutting, and very frequently precludes the possibility of repair.

With wheels not perfectly parallel, a condition to be found almost exclusively on the front wheels, there is liable to be a very great wear on the treads. This is inevitable, since both wheels must slide in a sidewise direction, quite as much as they can rotate, involving an unnecessary waste of good rubber.

THE CAUSE OF NON-PARALLELISM in the front wheels is generally to be found in a short or bent drag link between the steering arms, and this condition should be carefully searched for before other troubles are suspected.

SUDDEN BRAKING, although sometimes inevitable, as in attempting to avoid running down a foot passenger or colliding with any object in the road, is a frequent source of wear on rear-wheel tires. Causing the wheels to slide, before the momentum of the car is overcome, it must inevitably cause wear at the tread. For sake of preserving the tires, if for no other reason, the brake of an automobile should be thrown on as gradually as possible.

DIRECT-ACTING BRAKES, or shoe brakes, such as are used on heavy horse wagons with steel tires, are mentioned by some authorities as destructive to the treads of rubber pneumatics. They are practically never used on automobiles at the present day, and need not claim much of our attention. It may be said,

however, that their destructive action seems to be in inverse ratio to their bearing surface. With a direct-acting brake of sufficient surface to avoid concentration of strain on a limited area of tread, the wear would be very much less. One authority states that he has used such a shoe brake on a pneumatic tricycle tire for several years without harmful results.

DRIVING AGAINST CURBSTONES is often the occasion of wear upon the side walls of a tire. If frequently repeated the fabric will be exposed, and the destruction of the tire hastened. A driver should always avoid contact with a curbstone, since injuries to the wheels and tires are by no means warranted by the slight advantage gained in point of convenience to passengers.

**Chemical Action.**—Under the general head of chemical action we may include causes operating to corrode or rot any part of the tire. Chemical deterioration may affect both the rubber and the fabric, and in either case rapidly wrecks the tire. The best and strongest tires are as liable to chemical injury as any others.

THE RUBBER of a tire suffers chemical deterioration from the action of oil, gasoline or acids. These substances, whether carelessly dropped upon the tire or present at any part of the roadway over which it travels, are always destructive in their action. If, therefore, gasoline or oil are accidentally spilled upon a tire, it should be wiped clean as quickly as possible, and care should be exercised not to allow the wheels to stand in accidental puddles of oil on the table floor. Under the action of such substances rubber hardens, losing its elasticity and tenacity, and developing a tendency to wear and chip.

STRONG AND STEADY LIGHT, as well as high or changing temperature, is harmful to rubber. After a tire has been in use for some time it is less liable to suffer from light and heat than a new tire. However, no tire, new or old, should be exposed for extended periods in blazing sunlight Particularly, it must be said, it should never be left near a window, so that the sun shines through glass. Sunlight, under such conditions, tends to harden the rubber, causing it to develop cracks. Heat acts in similar fashion, although, unless excessive, far more slowly.

Extra tires carried on a car should always be kept in cases, such as are provided for the purpose by tire dealers. This rule applies with particular force to the very elastic air tubes, which should be stored in bags in some convenient place away from the light and heat of the sun. Many expensive air tubes have been unnecessarily ruined by lying loose in the wicker baskets at the sides of the tonneau.

Tires in use are not as liable to injury from sunlight as the extra stored tires, for the reason that the dust and mud of travel, while not directly contributing to the advantage of the rubber, seem to neutralize the ill effects of the sun's rays in an efficient manner. This is the best explanation of the fact that used tires are less liable to injury than new ones.

Chemical injury to the fabric or thread lining of a tire consists most usually in rotting from the presence of water or dampness. Injury by oil, acid, etc., is much more remote. On account of the liability of the fabric to be rotted by moisture, it is particularly desirable that the rubber be not allowed to wear away, so as to expose it.

Dampness acts on the fabric of stored tire far more quickly than water will act on canvas wholly immersed in it. Water has the peculiar faculty of penetrating even the minutest chinks or punctures, and is rapidly absorbed by the fibres composing the tire fabric. Only one result can follow: the fabric will be broken down and the case tube correspondingly weakened. Very frequently tires will burst from this cause, after being stored through the winter months.

When in constant use the fabric of a tire is very little in danger of deterioration from water, although dampness in the stable should always be avoided. A tire in use, however, is exposed to an ever graver danger: a cut in the tread of the case tube may admit sand or mud, which, working under the outer layer of rubber, will form a pocket, where water may collect and begin work on the fabric. Any sign of a cut or a *blister*—as lumps covering sand or mud are called—should warn the driver that the tire needs repair.

# CHAPTER TWELVE.

## CARE OF PNEUMATIC TIRES.

**Dimensions of Pneumatic Tires.**—Nearly the most important consideration in securing the best service from pneumatic tires is that they should be of sufficiently large dimensions for the load they are intended to carry. A large part of the troubles with tires, so conspicuous in former days, was due principally to the fact that they were too small for their loads. That they should be sufficiently inflated is also important. The proper dimensions and air-pressures for double-tube tires, as given by Michelin and other authorities, are found, as follows:

For loads between 350 pounds and a maximum of 600 pounds per wheel, 2½ inches diameter, inflation pressure, 50 pounds.

For loads between 440 and 660 pounds per wheel, 3⅓ inches diameter, inflation, 70 pounds.

For loads between 550 and 990 pounds per wheel, 3½ inches diameter, inflation, 71 to 78 pounds.

For loads between 660 and 1140 pounds per wheel, 4 inches diameter, inflation, 71 to 78 pounds.

For loads between 880 and 1320 pounds per wheel, 4⅔ inches diameter, inflation 71 to 78 pounds.

For loads between 1100 and 1650 pounds per wheel, 5½ inches diameter, inflation, 71 to 85 pounds.

The inflation pressure may be indicated by pressure gauges, such as are furnished by some supply houses, but may be judged sufficient when the tire stands firm under the load. A tire too small for the load will likely burst under pressure sufficient to render it firm.

**Care of Tires.**—In addition to the several principles stated in the foregoing chapter, it is necessary to dwell but little on

the matter of caring for tires, so as to prevent, as far as possible, the common mishaps.

1. A tire of proper size for the load carried, if kept properly inflated, is less liable to puncture than when allowed to become soft.

2. It is undesirable to overload a car, so as to bring more than the maximum pressure, as given above, upon each wheel. The rest of the machinery may endure it: the tires will suffer.

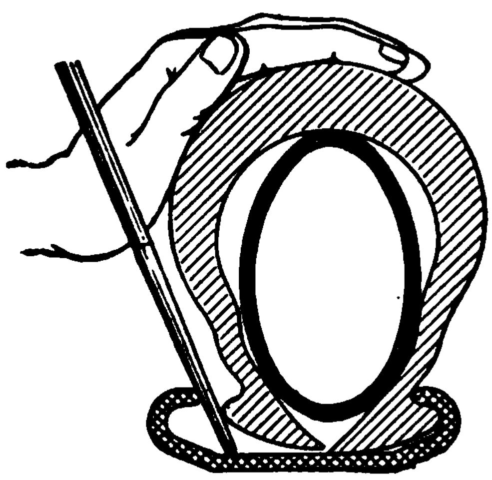


FIG. 101.

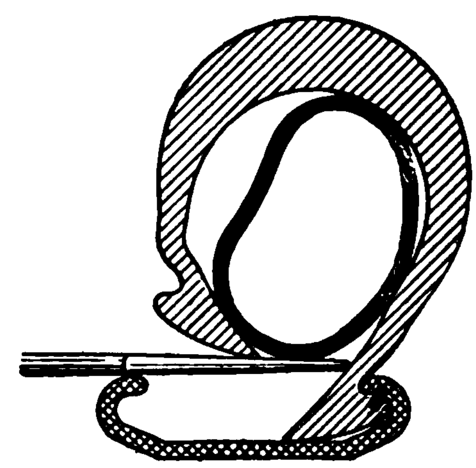


FIG. 102.

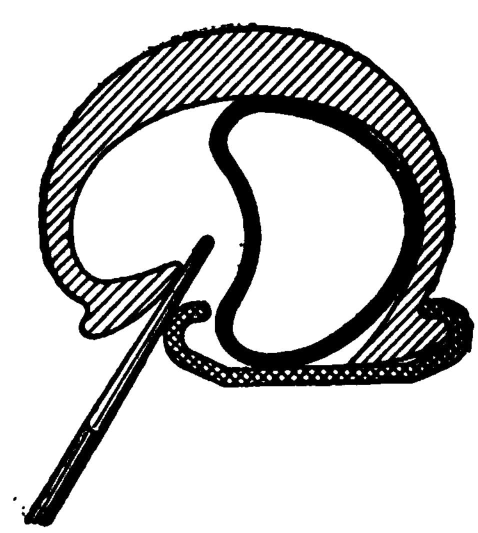


FIG. 103.

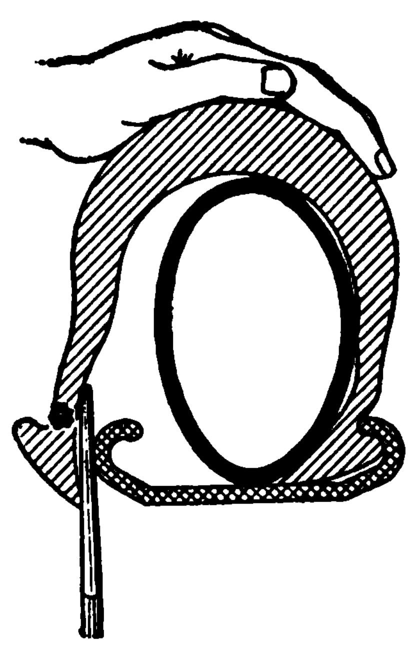


FIG. 104.

FIGS. 101-104.—Showing successive stages in the removal of the shoe or case-tube of a clincher pneumatic tire by the insertion of a tire tool.

This is one very excellent reason why pneumatic tires may not be used on commercial automobiles.

3. Excessive speeds are made possible—at least in the present stage of automobile design—by the use of pneumatic tires. The inevitable consequence, however, is the rapid destruction of the tires. Over-speeding is in this respect equivalent to overloading.

4. Sudden braking, which causes the tires to drag by restraining the rotation of the wheels, should be avoided, whenever possible. Tires so treated wear and tear rapidly.

5. Sudden, or short, turns, by distorting, or straining the tires, often results in tearing out and destruction.

6. A tire should never be allowed to rub against a curb stone or other low ridge. Running in a street car track is not the best practice, as it sometimes results in undue wear upon the tire treads, and occasionally causes cutting of the walls.

7. Any evidence of wearing or tearing of the tread or case tube should lead to speedy repair. Tears in the outer rubber cover generally increase in size, allowing sand and moisture

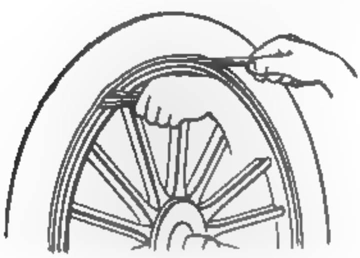


FIG. 105.

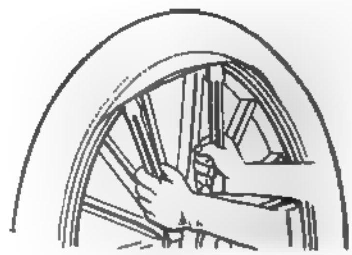


FIG. 106.

FIGS. 105-106.—Showing method of removing the case tube with two levers.

to work in, forming "blisters," injuring the fabric and tearing off the outer layer of rubber. It is well to have any tear, small or large, vulcanized as soon as possible, thus saving further trouble and expense. A new tread should be vulcanized on before the fabric of a tire is exposed.

8. Never allow a tire on a vehicle to become deflated. If it leaks, remove it for repair.

9. Particular care should be exercised, in removing and returning case tubes, not to rip or pinch the air tube, either with the tire tool or between the ends of the wall, or under the clips.

**Repair of Tires.**—Formerly books treating of tires included explicit directions for repairing punctured and injured tires.

Most of the rules and directions then given are out of date at the present day. Several reasons may be assigned for this statement:

1. The greater weight of the vehicles now in use causes considerable heating within the tire, particularly when the fabric is not securely united with the rubber in the case tube, or when it rips and tears in the tread. Often the mere movement of the tire generates considerable heat. This condition naturally destroys the effect of most rubber cements, such as are used for attaching patches to the inner tube, or for securing plugs in the case tube.

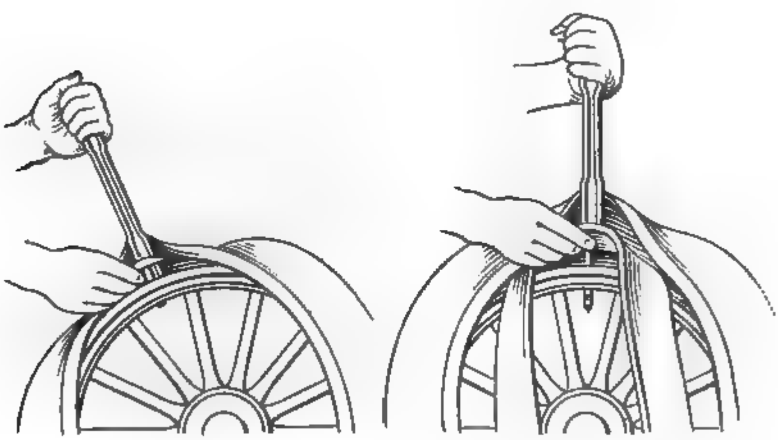


FIG. 107. FIG. 108.

FIGS. 107-108.—Showing method of removing the air tube with a single (stepped) lever.

2. The work of repairing an air tube is altogether too delicate an operation to be undertaken by any amateur. This is particularly true of large tubes intended to contain high pressures.

3. Experience warrants the statement that the common run of plugs, patches, foolish tire bands and all other repairs effected by the use of cement are worse than useless for present-day tires. Only vulcanizing can effectually remedy dam-

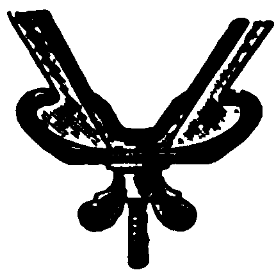


FIG. 109.

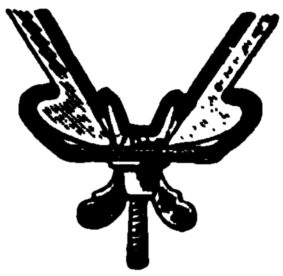


FIG. 109A.

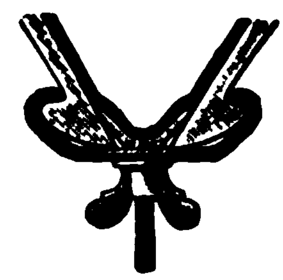


FIG. 109B.

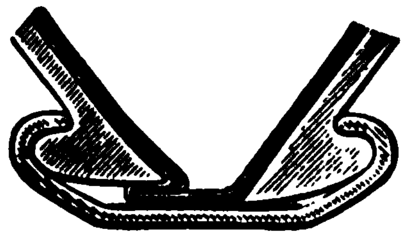


FIG. 110.

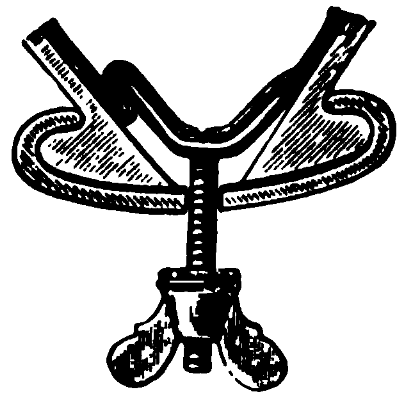


FIG. 111.

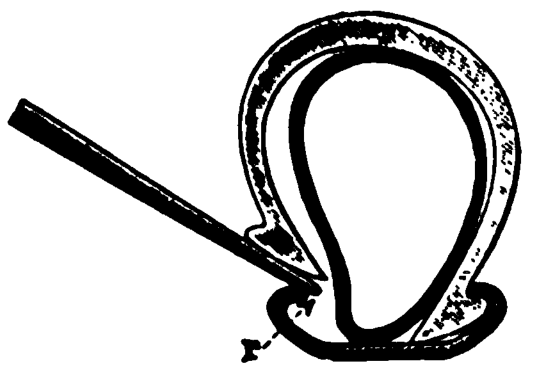


FIG. 112.

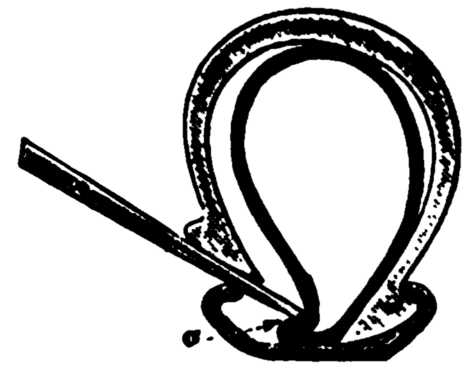


FIG. 113.

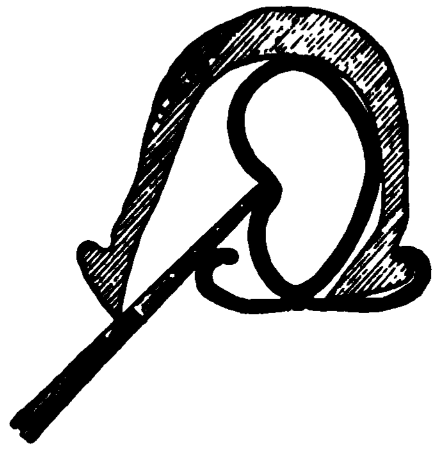


FIG. 114.

FIG. 115.

FIGS. 109-115.—Diagrams of various mishaps to pneumatic tires. Fig. 109 shows the air tube resting over a perfectly fitting chaplet head; Figs. 109A and 109B, the effects of poorly fitting chaplets, showing liability to pinching of the air tube; Fig. 110, air tube pinched under the edge of case tube; Fig. 111, air tube pinched by attempt to pull down chaplet—in both these cases the air tube is not sufficiently inflated while attaching the case tube; Figs. 112 and 115, the right and wrong way to raise the edge of the case tube over the clinch; Figs. 113 and 114, two ways in which the air tube may be nipped by allowing the tire tool to penetrate too far.

age encountered in any form of tire. Vulcanizing should always be done by a person thoroughly acquainted with working rubber.

An effectual method of guarding against disablement from tire accidents is to carry at least one extra case tube, and several extra air tubes. Both varieties of extra tube should be carefully wrapped and protected from sunlight and moisture. Moisture within the case tube will soon work destruction to the air tube.

Fig. 116. Fig. 117.

Figs. 116-117. Showing method of removing the air tube with a double lever.

In the event of being caught with no extra air tube, the damaged tube may be removed from the case, which may then be filled as nearly as possible with a coil of half-inch rope, wound around the rim, and stuffed into the case as far as it can be done, so as to prevent too much bending of the walls. The support thus formed will enable the case to be used at a slow speed, until the return home. If the tire is a clincher, the process of stuffing in the rope is tedious. If a side-flange tire is used, the process is far simpler.

# CHAPTER THIRTEEN.

## TYPES AND MERITS OF AUTOMOBILES.

**Types of Automobiles.**—Within the last three years the construction of automobiles, or motor-propelled road vehicles has been greatly modified and improved in a number of particulars. The troubles that were previously notable are now very nearly overcome, and in the case of steam, electric and gasoline carriages alike the ideal of a perfectly practical machine is rapidly being approximated. Neither has this gradual development of the ideal vehicle involved any such radical changes as some superficial and ill-informed persons have confidently predicted. True to the statements of practical experts, the leading features—such as steering and compensating apparatus, rear-wheel drive, resilient tires, and several other features—have remained the same. Only the details have been altered and improved in the gradual evolution of the practical out of the experimental. Furthermore, the steady tendency is toward a greater uniformity of design, rather than toward any eccentric or novel constructions; toward a perfecting of standard constructions already recognized, rather than toward anything entirely new and peculiar.

In another respect the development of the practical road carriage is notable: and that is, that types formerly prevalent are gradually lapsing in popularity, while others are gaining in corresponding ratio. Thus, steam carriages, which a few years since were manufactured by nearly two-score different concerns in this country, are at present built by scarcely half that number, and are sold in very small numbers. The electrical vehicle has taken its logical position as a means of freight and passenger traffic in cities and for short tours out of town; while the gasoline machine is rapidly gaining recognition as the automobile *par excellence*. Such changes in popular estimate of the three types of driving power are based almost entirely upon practical considerations, quite independent of the arguments that may be adduced by interested authorities and enthusiasts. Furthermore, the fore-

most considerations in the mind of the motor-using public refer almost entirely to ease of care and control and immunity from disablement. This explains the present pre-eminence of the gasoline machine, in which the sole requirement for starting is to crank the engine, thus saving the troubles incident on starting the fire, as in the steamer, or on caring for and recharging the battery, as in the electric.

**Advantages Analyzed.**—In a recent number of a well-known automobile journal (*Motor,* New York), the several advantages of the three types of machine are set forth by prominent experts.

Speaking for the steam vehicle, Windsor T. White specifies the following twelve advantages: (1) Practical absence of jar and noise; (2) ease of control—throttling instead of gear shifting by levers; (3) absence of gearing between the engine and the drive axle; (4) flexibility of the steam engine, permitting any speed, from highest to lowest, with nearly even power efficiency; (5) continuous application of power in each cylinder, instead of a power stroke in each two revolutions, as with the four-cycle gasoline engine; (6) ease of lubrication in the comparatively cool cylinder, and absence of trouble from over-oiling; (7) the fact that the steam engine is better understood by the average man than either of the other motive powers; (8) from this reason, the greater ease of having roadside repairs made; (9) a combination of flash generator, automatic fuel regulation, compound engine and direct drive gives the most satisfactory machine for inexpert operators; (10) certain and invariable automatic regulation dependent solely on the physical properties of varying temperature and pressure; (11) complete elimination of boiler troubles, scaling, etc., by the use of the flash generator; (12) complete immunity from burning out, with the combination of flash generator and thermostatic regulation.

Mr. White is speaking, of course, of a carriage using the flash-line system of generation, as embodied in the machines built by his company, which have proved of the greatest advantage for this purpose since the time of Serpollet's first invention of this apparatus in 1889. With other types of generator and regulator the advantages are less conspicuous. Mervyn O'Gorman, an English authority, states the case of the average steam carriage from both sides. As ten advantages: (1) Absence of speed gears;

(2) saving of wear, tear and noise; (3) high power-outputs for short periods for climbing hills and traveling on rough roads; (4) greater speed uphill, and greater average speed for original cost; (5) proportionate fuel consumption and power efficiency; (6) cleanliness equal to petrol motors; (7) absence of the troublesome ignition system, as on petrol motors; (8) absence of exhaust noises, back-shots, pre-ignition, etc.; (9) cheapness in first cost; (10) starting without cranking, therefore stillness of the car in standing. As sixteen disadvantages: (1) The need of extinguishing the fire during stoppages; (2) the consequent trouble of re-igniting the burner; (3) the great loss of fuel, due to not extinguishing; (4) the need for greater attention, owing to the number of adjustments not automatic; (5) limited capacity for carrying fuel and water supply; (6) heavy fuel consumption, generally twice that of gasoline carriages of the same power; (7) heavy water consumption, and the need for constant refills; (8) fouling of the boiler tubes—in some types; (9) vitiation of the air by burned products in greater volume than with gasoline motors; (10) loss of time in starting from a cold boiler; (11) greater dangers from neglect, such as seizing and heating from insufficient lubrication, grave consequences in failure of water system, priming from high water and consequent knocking of the pistons, evil effects of feeding oil into any type of boiler or generator, clogging of valves or failure of pumps; (12) the troubles, due to wind blowing down upon the fire; (13) stoppage of safety valves; (14) necessity of using soft water for boilers; (15) trouble of cleaning the flues; (16) issue of visible steam mixed with oil liable to stain clothes.

Setting forth the advantages of the gasoline carriage, Elmer Apperson enumerates the following twelve points: (1) Availability of fuel, readily obtainable anywhere; (2) convenience in renewing the supply, no fire being present that must be extinguished; (3) economy of fuel, owing (*a*) to none being used when the machine is standing, (*b*) to the small amount used when running light, (*c*) to the high efficiency of the gasoline engine —twenty-five or thirty per cent. as against ten per cent. for the steam engine, and less for the electric motor; (4) perfect throttling system for changing the speed and power ratios; (5) noiselessness, as achieved in the later types of motor; (6) ease of using in winter with non-freezing jacket solutions; (7) the absence of

indicating devices to distract the mind of the operator; (8) absence of constant fire, as in a steam machine to "make a volcano of the slightest leak"; (9) rareness of total disablement, as against steam or gasoline machines; (10) extended travel radius, gasoline machines having been run 1,000 miles without a stop, as against the record of 100 miles for a steamer, and the average of 30 or 40 miles per charge for the electric; (11) the greater perfection of the gasoline machine, on account of the thought and labor expended in its development; (12) that it can be built with any style of body, for any kind of service, and holds all records for speed and endurance.

The claims of the electric carriage are set forth by Walter C. Baker under the following twelve heads: (1) The superior material of the electric carriage, together with its durability and attractiveness; (2) the speed range, greater than a horse at low speed and within legal limits at top speed; (3) the small care required in comparison with other types of power, the smallest attention yielding the best results—the battery alone demanding particular care; (4) the ideal source of energy found in the storage battery, which is compact, clean, safe, and able to yield instantly to the will of the operator; (5) freedom from noise, odor or vibration; (6) with all mechanical parts rotating, anti-friction bearings may be used throughout, enabling great results from little power; (7) the slight physical effort required to manage it; (8) absence of oil, fire, water and pumps leaves nothing to freeze, burn, or explode, and requires no pumping at the start; (9) absence of lubricants renders it clean; (10) safety for ladies and convenience for short tours; (11) small number of occasions for failure to run; (12) a single lever to control the motive power, and another for steering, rendering it the simplest of all to manage.

## CHAPTER FOURTEEN.

### THE THEORY OF HEAT ENGINES.

**Power Derived from Heat.**—Both steam and gas engines are forms of heat motor; since both operate by means of the expansive energy of gases, which have been subjected to the action of heat. A permanent gas, or the vapor from a liquid or solid substance, when exposed to heat tends to expand, and, in expanding, exerts an active pressure in all directions. Thus, if a gas, or a readily volatized liquid, like water or alcohol, contained in a corked vessel, be exposed to heat, the expansion will be exhibited in the expulsion of the cork. In this fact it demonstrated the principle, on which all forms of heat engine operate—that heat may be transformed into mechanical energy through its effects on liquids and gases, promoting the change from fluid to gaseous state and then increasing the volume of the gas. No state of matter is entirely permanent, and, as a general rule, the absorption of a sufficient quantity of heat results in liquefying a solid, and in vaporizing a liquid. Gases subjected to heat, either when ignited, as with inflammable gases, or merely heated as with separated steam, tend to assume greater volumes so long as the temperature is not allowed to fall. On the other hand, modern science has succeeded in producing liquid air and liquid carbonic acid gas by the combination of extremely high pressures and extremely low temperatures. It is sufficient to say that no pressure has yet been found sufficiently high to liquefy air, without the cooperation of a temperature commensurately low. Conversely, also, no known degree of cold can produce this effect, apart from a high pressure acting at the same time.

**Principles of Pressure and Temperature in Gases.**—A leading property of gases is that, the temperature remaining the same, an increase in volume involves a corresponding decrease in

pressure, and, that to maintain even a constant pressure in an expanding gas, the temperature must be raised on a steadily increasing ratio. In other words, a given cubit content of expanding gas, at a constant temperature, shows a lower pressure per square inch as the expansion progresses, and, in order to obtain a given total original efficient pressure the cubic content of the cylinder must increase with the expansion. On the other hand, if a given cubic content of gas be compressed to half its normal volume, without involving an accompanying increase in temperature, the pressure is doubled. In either case, an undue increase of temperature operates to neutralize the stated principle.

From these facts we may deduce the principles that:

1. The inherent pressure of a gas varies inversely with the volume and directly with the temperature.

2. The volume of a gas varies inversely with the pressure and directly with the temperature.

3. The inherent temperature of a gas varies directly with the pressure and inversely with the volume.

To state these principles in another way, we may say:

1. An increased pressure involves a decreased volume or an increased temperature.

2. An increased volume involves a decreased pressure or an increased temperature.

3. An increased temperature involves an increased volume and an increased pressure.

As the operative conditions in a heat engine are immensely irregular no formulae can precisely express the proper temperature, volume or pressure for theoretical situations. Since, however, the attributes of the gas at various points in the cycle are in direct proportion to the dimensions of the cylinder, the length of the stroke, the cubic content of the clearance, and other familiar physical and mechanical conditions, very satisfactory figures may be found to express the power and capacity of any particular engine.

**The Law of Pressure and Volume of Gases.**—The physical properties of gases in general are defined by two familiar laws —the first defining the degrees of volume and pressure at constantly maintained temperatures; the second, the ratio of expansion at a constantly increasing temperature. The first, known as *Boyle's Law*, states that

THE VOLUME OF A GAS VARIES INVERSELY AS THE PRESSURE, SO LONG AS THE TEMPERATURE REMAINS THE SAME, OR, THE PRESSURE OF A GAS IS PROPORTIONAL TO ITS DENSITY.

This law has frequently been illustrated by the following experiment:

If we take a hollow cylinder, such as is used on steam engines, having a piston sliding airtight in its length, we will find that the contained, air or other gas, is compressed in front of the piston, as it is forced from one end toward the other of the base, and that this air, or gas, exerts a pressure which increases in ratio as the volume is diminished. This fact may be shown by inserting in the wall of the cylinder a tube containing an airtight piston, upon which bears a spiral spring holding it normally, as at *A* in the accompanying diagram; the pressure there being supposedly equal on both sides of the piston, or equivalent to 15 pounds per square inch. If, now, the area of this small piston be exactly one square inch, and the spring of such a tension as to move upward through one of the spaces between the lines on the diagram behind the large cylinder with each ten pounds of added pressure from below, the result will be as follows: When the piston of the large cylinder has been pushed through one-half its length, the depression of the spring in the smaller one will show that the pressure is just twice what it was at the start, or 30 pounds. At three-quarters the stroke it will show sixty pounds, and at seven-eighths, 120 pounds. If the four smaller cylinders be arranged in the wall of the cylinder, as in the diagram, the difference in pressure at these several points may be graphically represented. Then a curve, drawn so as to pass through the center of each of the smaller pistons, will give an accurate average of pressure

for every position of the large piston. On the other hand, as under the operative conditions in a steam engine, it will represent the "curve of expansion," or the decrease in pressure from

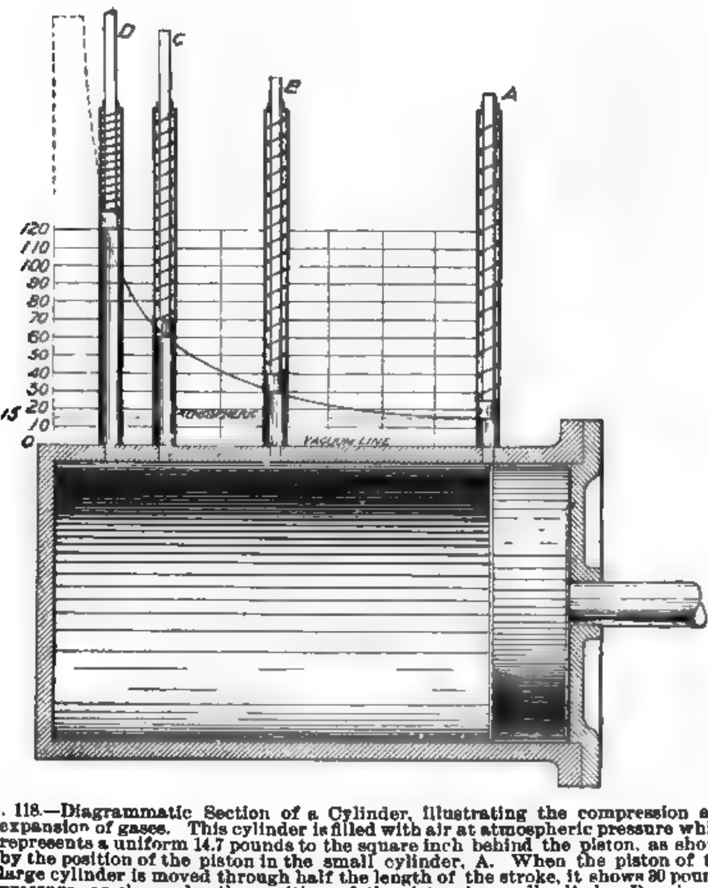



FIG. 118.—Diagrammatic Section of a Cylinder, illustrating the compression and expansion of gases. This cylinder is filled with air at atmospheric pressure which represents a uniform 14.7 pounds to the square inch behind the piston, as shown by the position of the piston in the small cylinder, A. When the piston of the large cylinder is moved through half the length of the stroke, it shows 30 pounds pressure, as shown by the position of the piston in small cylinder, B; when at three-quarters stroke 60 pounds, as shown by the position of the piston, C; when at seven-eighths stroke, 120 pounds, as shown by position of piston, D. At full stroke it would be 240 pounds, the diagram behind the small piston giving the compression curve from 15 to 240.

the moment of "cut-off," when the inlet valve is closed to the end of the stroke, when the exhaust valve is opened. If, therefore, steam be fed into the cylinder at 200 pounds pressure per square

inch, and the inlet be closed when the piston has traversed one-eighth of the stroke, the pressure will stand at 100 pounds on quarter-stroke; at 50 pounds on half stroke, and, at 25 pounds on the point of completed stroke, which shows that it is expanded four times.

Very similar conditions exist in the cylinder of a gas engine, as will be shown later. Here, the expansion of the gas in cylinder is estimated from the moment of maximum pressure, when the fuel charge has reached the height of its temperature, due to its ignition by electric spark or other source of firing.

In both the cases in the diagram, the temperature is supposed to remain constant, while the pressure increases, on the one hand, or decreases on the other. Such compression and expansion would be entirely *adiabatic,* taking place without loss or gain of heat, but this is a condition never met in practice.

**The Temperature and Volume of Gases.**—The "second law of gases," called *Charles* or *Gay Lussac's law,* states that

AT CONSTANT PRESSURE THE VOLUME OF A GAS VARIES WITH THE TEMPERATURE, THE INCREASE BEING IN PROPORTION TO THE CHANGE OF TEMPERATURE AND THE VOLUME OF THE GAS AT ZERO.

By actual experiment it has been ascertained that a gas increases on a ratio of 1-493d part of its volume at 32° Fahrenheit, with each additional degree added to its temperature. This places the "absolute zero," or the point at which a gas would assume its greatest possible density at −461°, Fahrenheit, or —273°, Centigrade.

**Absolute Figures for Temperature.**—In temperature and pressure calculations for heat engines, it is customary to use absolute figures, so called, as based upon the data just given. Thus, the absolute temperature is the sum of the sensible thermometric temperature and the constant 461. This latter figure, which is more properly expressed as 460.66, represents the total number of degrees on the Fahrenheit scale from 32° below the

Freezing point of water to absolute zero of temperature, as calculated by the expansion ratio of gases. Thus in calculating temperatures, we count from absolute zero; instead of 64°, writing 525°, and instead of °32, writing 493°, or, more correctly, 492.66°. The utility of this system lies in the fact that, as a gas has been found to expand by 1-273 of its original volume for each degree, centigrade, or by 1-461 for each degree, Fahrenheit, of increased temperature, we have by the use of absolute figures an approximate expression for both increased heat and increased volume in the same number.

The absolute zero is the point of theoretically complete stability of a gas.

**Absolute Figures for Pressure.**—Similarly, the *absolute pressure* is given as the sum of the gauge pressure and the constant 15 (more correctly 14.7), representing the total pressure above zero acting against atmosphere. Since, in a guage, or in the cylinder of a heat engine, the effective power is acting against the pressure of the atmosphere, which is 14.7 lbs. per square inch, the recorded pressure always represents the actual pressure less 14.7. The pressure and temperature of a gas being strictly in ratio, it is possible to determine the temperature, approximately at least from the guage pressure. The correspondents of temperature and pressure for various gases may be determined by knowledge of their physical properties. For steam they have been completely tabulated, as shown in the following columns, which contain averages on several authorities:

| Pressure. | Temperature. | Pressure. | Temperature. | Pressure. | Temperature. |
|---|---|---|---|---|---|
| 15 lbs. | — 212° F. | 55 lbs. | — 288° F. | 100 lbs. | — 330° F. |
| 20 lbs. | — 228° F. | 60 lbs. | — 294° F. | 105 lbs. | — 333° F. |
| 25 lbs. | — 241° F. | 65 lbs. | — 299° F. | 120 lbs. | — 343° F. |
| 30 lbs. | — 252° F. | 70 lbs. | — 304° F. | 135 lbs. | — 352° F. |
| 35 lbs. | — 261° F. | 75 lbs. | — 309° F. | 150 lbs. | — 362° F. |
| 40 lbs. | — 268° F. | 80 lbs. | — 313° F. | 165 lbs. | — 369° F. |
| 45 lbs. | — 275° F. | 85 lbs. | — 316° F. | 180 lbs. | — 375° F. |
| 50 lbs. | — 282° F. | 90 lbs. | — 322° F. | 195 lbs. | — 383° F. |

**Determining the Temperature from the Pressure.**—Although saturated steam, or steam existing in and fed direct from

the boiler in which it is generated, and so called because it holds considerable unvaporized water in solution, is not a perfect gas, the operative conditions in a steam engine are fairly typical for any form of motor operating through the expansive effect of heat upon gases.

In order to explain the process for a cylinder expanding 1-10 pound of steam from 120 pounds per square inch pressure to atmosphere. The following passage quoted from Forney's "Catechism of the Locomotive," is sufficient:

"If the piston stand at the point shown in the previous figure, and 1-10 pound of water be put into the cylinder, and heat be applied to it, it would

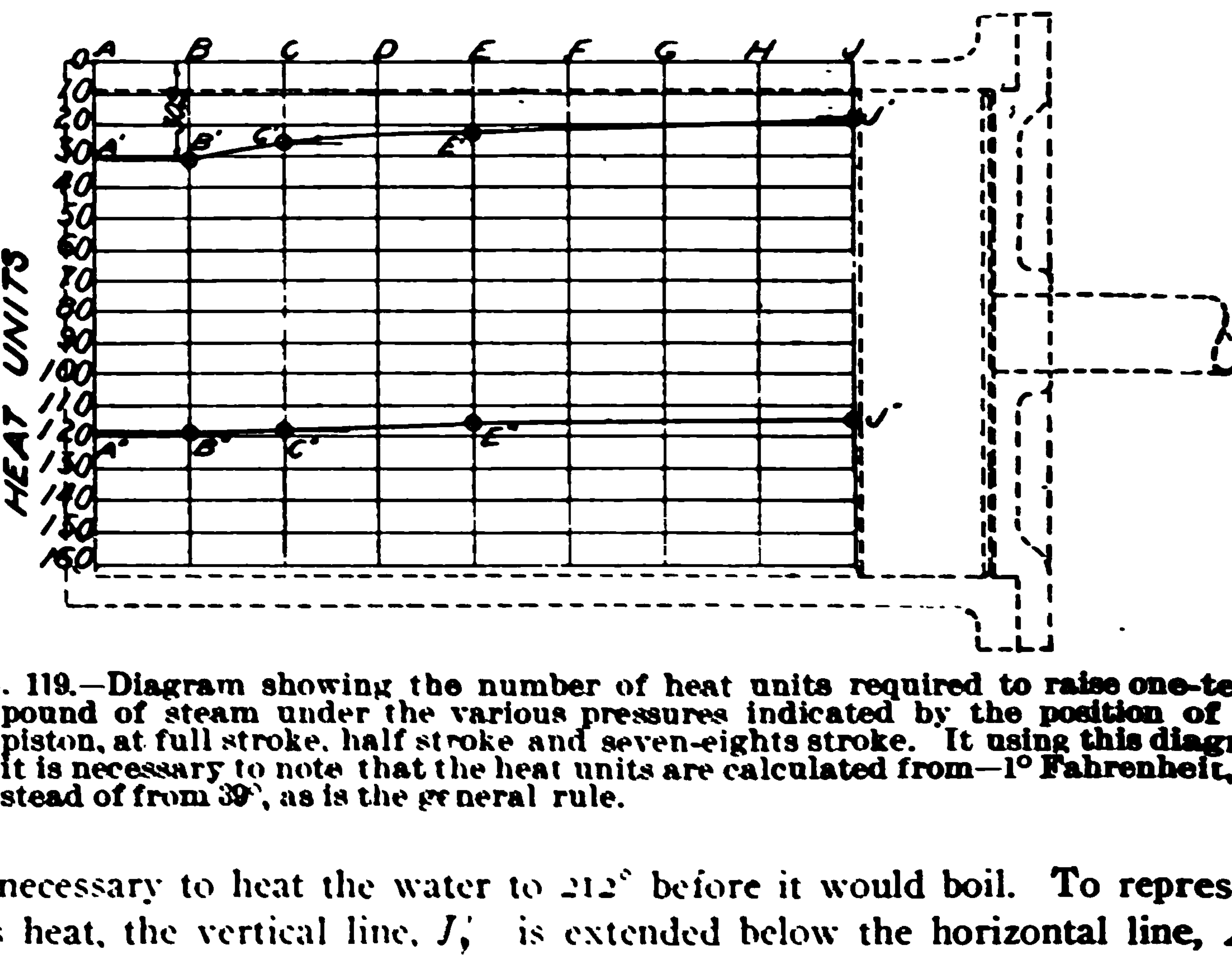



FIG. 119.—Diagram showing the number of heat units required to raise one-tenth pound of steam under the various pressures indicated by the position of the piston, at full stroke, half stroke and seven-eights stroke. It using this diagram it is necessary to note that the heat units are calculated from—1° Fahrenheit, instead of from 39°, as is the general rule.

be necessary to heat the water to 212° before it would boil. To represent this heat, the vertical line, *J*, is extended below the horizontal line, *AJ*. To heat 1-10 pound of water to 212° takes 21.2 units of heat,—since one unit of heat is required to raise one pound of water at 39° Fahrenheit to one degree above—which is laid off from *J* to J' to the scale represented by the horizontal lines. But as is shown in the table in the appendix, after the water begins to boil, 96.6 more units of heat must be added to it to convert it all into steam of atmospheric pressure. This number of units of heat is, therefore, laid off from *J* to *J*." If the piston be moved to *E*, the middle of the cylinder, and 1-10 pound of water is again put into it, and it is all converted into steam, it will have a pressure of 30 pounds per square inch, as it occupies only half the volume that the same quantity

of steam did before. To make water boil under a pressure of 30 pounds, it must be heated to a temperature of 250.4°, which in this case will require 25 units of heat, which is laid down from $E$ to $E'$. To convert the water into steam, after it begins to boil, will require 93.9 more units of heat, which is also laid down from $E$ to $E''$. In the same way the total heat to boil and convert 1-10 pound of water into steam at 60 and 120 pounds pressure, as shown in the appendix, is laid down on $C\ C''$ and $B\ B''$, and the two curves, $B'\ C'\ E'\ J'$ and $B''\ C''\ E''\ J''$, are drawn through the points which have been laid down. The vertical distance of the one curve from $A\ J$ represents the heat units required to boil 1-10 pound of water at the pressures indicated by the curve in the previous figure, and the vertical distance of the second curve from $A\ J$ represents the total units of heat required to convert 1-10 pound of water into steam of a volume indicated by the horizontal distance of any point of the curve from $A\ A''$, and when pressure is indicated by the expansion curve above. This curve and the heat diagram may be very conveniently combined by adding the latter below the vacuum line of the former. The relation of the volume pressure and total heat is thus shown very clearly."

**Joule's Law of Temperature and Pressure.**—As may be readily understood from what has already been said, the recognized principle in the operation of all forms of heat engine is that

THE WORK-PRODUCING OR DYNAMIC PROPERTY OF A GAS DEPENDS SOLELY UPON ITS TEMPERATURE.

This is, substantially, a statement of *Joule's law,* which compares the temperature of a gas, enabling it to exert a certain amount of power, to the stored energy represented in a body of a certain weight raised to a certain height above the ground. The body, in falling under the force of gravity, obtains a certain degree of acceleration, constantly increasing, by which the weight falling through the given distance is transformed into a force capable of producing a commensurate effect of impact on reaching the earth's surface. This potential energy of a substance, represented either by an acquired temperature or some analogous physical condition, which, under favorable circumstances, would enable the production of a definite amount of work, is known as "entropy." Could the whole power of a heated gas be realized in its expansion—which is to say, could its expansion be perfectly "adiabatic," or "isentropic," involving neither gain nor loss of

heat in the process—we should have a theoretically perfect expansion curve on every practical heat engine. This is impossible, however, with the best arrangements yet contrived. Hence it is that the expansion curves of all engines fall far below what is demanded by theory from the original temperature and pressure of the steam, which involves that the final volume and the actual work accomplished are correspondingly diminished.

To quote from an authority on steam engines, "as we cannot take into consideration all the conditions which govern and modify the cycle of any motor, the usual practice is to calculate the power on the assumption that all theoretical conditions are complied with, and then modify the result by a certain co-efficient of efficiency which practice has established for the particular type of motor under consideration."

**The Steam Engine Indicator and Its Diagram.**—The action of the small cylinders containing springs and pistons as explained in connection with Fig. 118, very well illustrates the operation of the steam engine indicator in tracing the diagram, or "card," which reveals so much on the conditions within the cylinder. The simplest form of this instrument has a cylinder identical with those shown in the figure, except for a pencil carried on the uppermost end of the piston rod, and bearing upon a suitable tablet, which is moved backward and forward with the stroke of the steam piston. This is done by attaching the long arm of a reducing lever to the cross head, and the shorter arm to a link-bar, which holds the card, or tablet, to be inscribed. The line traced by the pencil point will rise or fall, as the pressure within the small cylinder is increased or reduced. The several forms of the indicator most often used at the present day have a rotatable drum, which is attached by a cord to the short arm of the reducing lever, so as to be turned in one direction; being moved in the other direction by a contained spring, which rewinds the cord, so soon as the lever arm moves backward. Thus the records of a great number of strokes may be taken on one sheet of paper.

The records thus made, by knowing the dimensions of the cylinder and the tension, or resisting strength, of the steam-actuated spring, may be very accurately calculated for the entire cycle of the engine.

**The Indicator Diagram and the Steam Engine Cycle.**—The operative efficiency of an engine may be very well determined from the indicator diagram, which gives a pictorial representation of the internal conditions throughout the entire cycle of operations. As given by a noted authority, already quoted, the steam engine diagram tells eleven different things essential to be known:

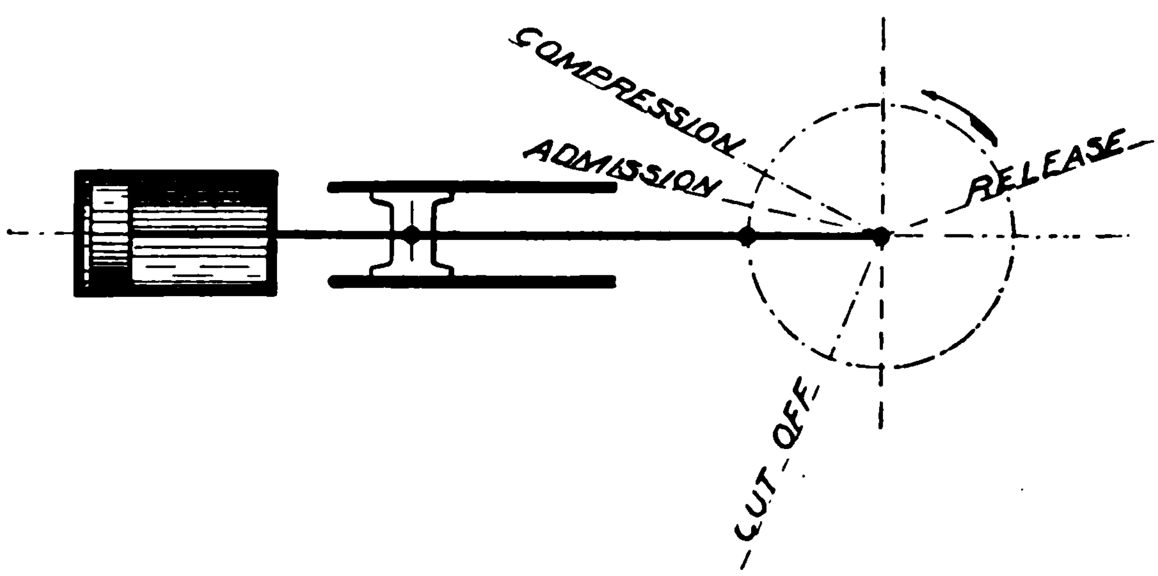



**FIG. 120.—Diagram of the Cycle of a Steam Engine.**

1. It gives the *initial pressure,* or the pressure at beginning of the stroke.

2. It tells whether the pressure is increased or diminished during the period of admission.

3. It gives the point of cut-off, when the valve is closed and expansion begins.

4. It indicates the rate and pressure of expansion during the whole period of expansion.

5. It gives the "point of release," when the exhaust is opened.

6. It shows the rapidity of the exhaust.

7. It gives the degree of back-pressure on the piston, due to the exhaust having closed, preventing further expansion.

8. It shows the point of closing the exhaust.

9. It shows the *compression* of the residual steam in the clearance after closing the exhaust.

10. It gives the mean power used in driving the engine.

11. In indicates any leakage of valves or piston.

**The Indicator Diagram and the Gas Engine Cycle.**—In precisely similar fashion, the indicator diagram reveals nine things regarding the operative conditions in the cylinder of a gas engine:

1. It gives the initial pressure from beginning to end of the inlet stroke.

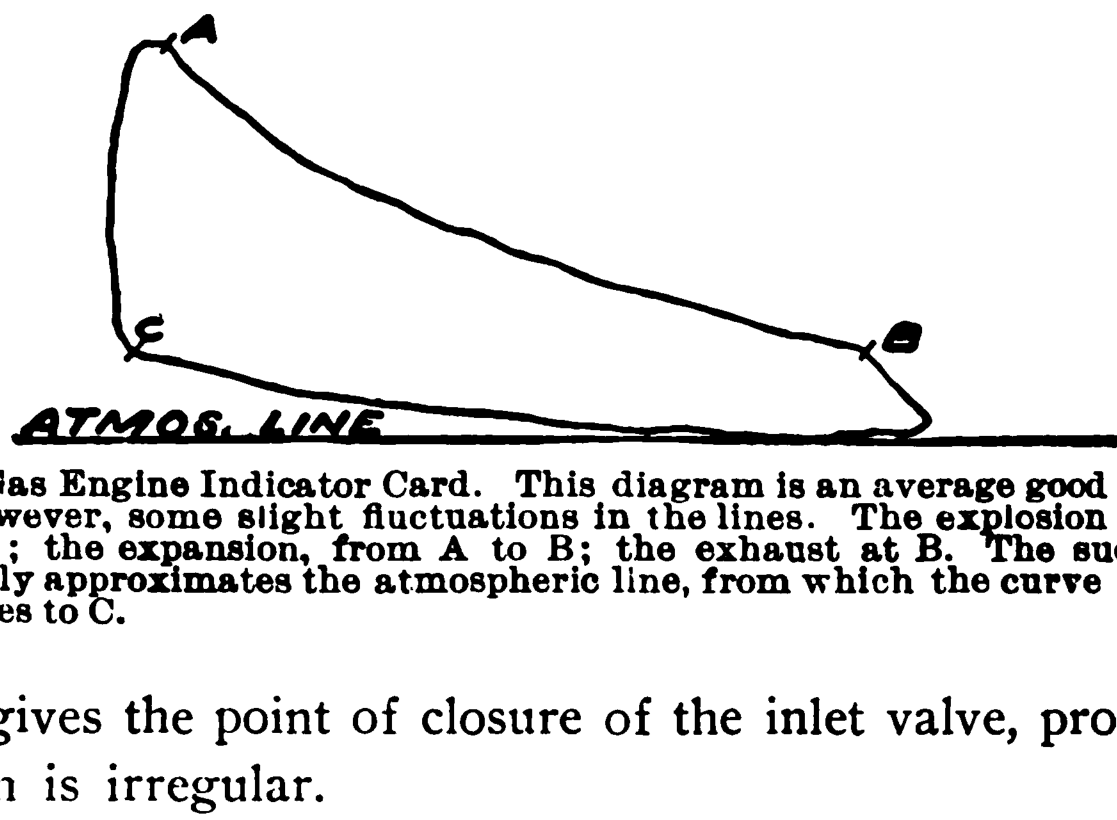



FIG. 121.—Gas Engine Indicator Card. This diagram is an average good card, showing, however, some slight fluctuations in the lines. The explosion line is from C to A; the expansion, from A to B; the exhaust at B. The suction stroke generally approximates the atmospheric line, from which the curve of compression rises to C.

2. It gives the point of closure of the inlet valve, provided the operation is irregular.

3. It gives the curve of compression, registering the highest point of compression pressure.

5. It gives the maximum pressure at the ignition of the charge.

6. It shows whether the ignition is normal or irregular, as shown in Fig. 133.

7. It shows the curve of expansion, indicating whether leakage or other disorder interferes with the full effective pressure.

8. It shows the point of exhaust, enabling a ready computation of the exhaust pressure.

9. It enables a ready estimate of the mean effective pressure.

**The Steam Engine Diagram.**—The diagram for a high-pressure steam cylinder is given in an accompanying figure. From point, *A,* the pressure rises from the compression maximum of about 50 lbs. to 120 lbs. as the steam enters the cylinder. The cut-off occurs in this cylinder at one-quarter stroke, the expansion starting at point, *C,* and continuing to the opening of the exhaust valve at point, *R.* From this point to *B*, where the exhaust valve closes, the returning in-stroke of the piston drives the steam out through the open exhaust port. The steam then remaining in the cylinder is compressed between points, *B* and *A,* being raised in pressure from a point near atmosphere to 50 lbs. gauge.

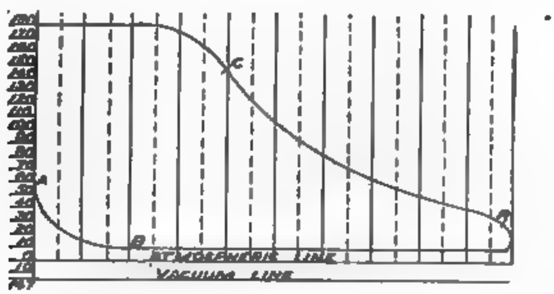



FIG. 122.—The Cycle of a Steam Engine, as shown by the Indicator Card. On this tracing, the admission is shown from A to C; the cut-off at C; the expansion curve from C to R; the release, or opening of the exhaust, at R, exhaust continuing from R to B; closing of the exhaust valve at B; compression of the residual steam in the cylinder clearance, from B to A. The figures on the left-hand vertical line indicate the gauge pressures.

All these stages are more graphically illustrated in the accompanying diagram of the cycle of a steam engine for the steam admitted to one face of the piston. In this figure the dotted circle indicates the path of the crank; the arrow, the direction of rotation. The admission begins a little before the completion of the stroke; the cut-off is set somewhat less than quarter-stroke; release, or opening of the exhaust, at somewhat over half-stroke; closing of the valve at the point marked "compression," after which the steam behind the piston is compressed in the clearance until the opening of the inlet valve.

**Reading an Indicator Diagram.**—The simplest method of reading a diagram, so as to find the power exacted, is to rule

equidistant lines from the vertical initial pressure line, so as to divide into ten equal parts, or areas. Ordinates, indicated by the dotted lines, are then ruled between these, and given a value equivalent to the average of pressure represented by the lines on either side, as indicated by the point of contact with the admission line and the expansion curve. Thus in the single high-pressure diagram the first ordinate ruled on the admission line has a value of 155 pounds, which represents 180 less 25 back pressure. The second and third ordinates, according to the figures ruled on the left-hand vertical line, have a value of 180 pounds; the fourth, of 165; the fifth, 128; the sixth, 98; the seventh, 80; the eighth, 68; the ninth, 55; the tenth, 50; showing an expansion of over three volumes from boiler pressure. The sum of the pressures given is 1149, which divided by 10, the number of the ordinates, gives the average of all the pressures acting on the piston during the stroke, or what is known as the *mean effective pressure,* at about 115 pounds.

In similar fashion the diagram for both strokes, inward and outward, of the piston is ruled off and estimated, the figures at the top of the figure indicating the cycle of pressure changes for the right-hand stroke, those at the bottom the cycle for the left-hand, or return, stroke.

**Calculating by the Mean Ordinate.**—A simpler method for calculating the diagram of a steam or gas engine is to find the mean ordinate of the diagram by the following process: Find the centre of the diagram figure on the base line; erect a line perpendicular to the base from that point; draw another line from the base so that it touches the expansion line at about the point of exhaust valve opening, at such an angle that the two parts on either side of the centre line will be equal measuring from a perpendicular on the explosion line on the one side, and from another touching the "toe" of the tracing on the opposite side. The portion of the centre line thus laid off by intersection is the mean ordinate, which, multiplied by the pressure indicated by the gauge gives the mean effective pressure (M. E. P.).

## CHAPTER FIFTEEN.

### THE PARTS OF A GAS ENGINE.

**Gas Engine Cylinder.**—The cylinder of a gas engine is open at the end toward the crank, and closed at the opposite end, save for the inlet and exhaust ports, which are opened and closed by valves.

**Gas Engine Pistons.**—The piston is single-acting—which is to say, acted upon by the power on one face only, or moved by power impulse in one direction only. It is of the type known as "trunk piston," consisting of a cylindrical box of proper size to slide back and forth in the cylinder bore.

The portion of the cylinder length traversed by the piston from end to end of the stroke is called the *sweep.*

That portion at the rear of the cylinder that is never swept by the piston is called the *clearance.*

The valve chamber opens into the clearance, and the ignition apparatus is also located here.

**The Clearance.**—The clearance determines the degree of compression of the fuel mixture at extreme *in-stroke,* when the piston has reached its furthest point in backward travel.

It is the *combustion space,* or *chamber,* at the moment of igniting the gas.

With the piston sweep, it forms the total *cubical content* of the cylinder, as found at extreme out-stroke, when the piston has reached its utmost forward point of travel.

**Piston Construction and Proportions.**—The trunk piston is hollow, and within it is pivoted the connecting rod, the opposite end of which is pivoted to the crank pin. Within the piston the connecting rod is pivoted to a pin, variously called the piston pin, wrist pin and gudgeon pin.

The piston is in diameter about .002 inch smaller than the cylinder bore, thus giving a clearance of about .001 inch all

around. A snug working fit is obtained by means of packing rings, iron rings so cut that the internal and external circumferences are eccentric, as shown in an accompanying figure, for the purpose of allowing some play for expansion, under the extraordinary heat generated by combustion of the fuel charge.

**Piston Rings.**—The piston rings fit into grooves cut around the circumference of the piston, and are set in place by being sprung over the junk rings, or the portions of the cylinder cir-

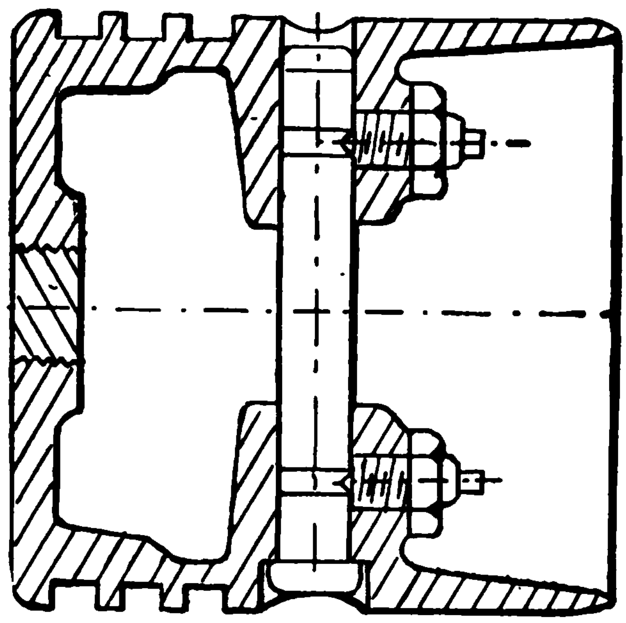


FIG. 123.—Section through a typical Trunk Piston for a Gasoline Engine. Around the circumference, near the rear end, are three circular grooves for inserting the packing rings. Through the central diameter is a perforation for admitting the piston pin, which is held in place by square-headed screws.
The proportions of the piston pin must be carefully calculated for the load it is intended to bear. In general, the length of the piston pin should be equal to that of the crank pin, and its diameter such as to bear an average of 750 pounds for each square inch of its projected area. As given by Roberts, the proper diameter of the pin may be determined as follows:

$$\text{Diameter} = \frac{\text{Cylinder area} \times \text{M. E. P.}}{750 \times \text{length of pin.}}$$

cumference left after cutting the grooves. Three or four rings are set around the piston at the rear end, and, in some engines, there is another around the front end.

**Machining Piston Rings.**—Piston rings are made of cast iron, and are cut from a pipe-shaped casting. The casting is secured to the lathe chuck, so that a cutting tool can bear against its circumference and separate rings of the proper width. Each ring is then turned in a jig, so that the inner circumference is eccentric with the outer, and a slit is cut in the thinnest section, as shown in the figure. Although formed

of a very brittle substance, piston rings have considerable elasticity; being capable of opening sufficiently to be slid over the junk rings of the piston, also allowing of sufficient compression when within the cylinder, to make a tight fit.

**Poppet Valves.**—The inlet and exhaust ports of a gas engine of the four-cycle type are opened and closed by *poppet* or *mushroom valves.* These consist of metal disks, beveled around one face, so as to fit into a countersink in the port opening, and carried upon *stems* or *spindles.*

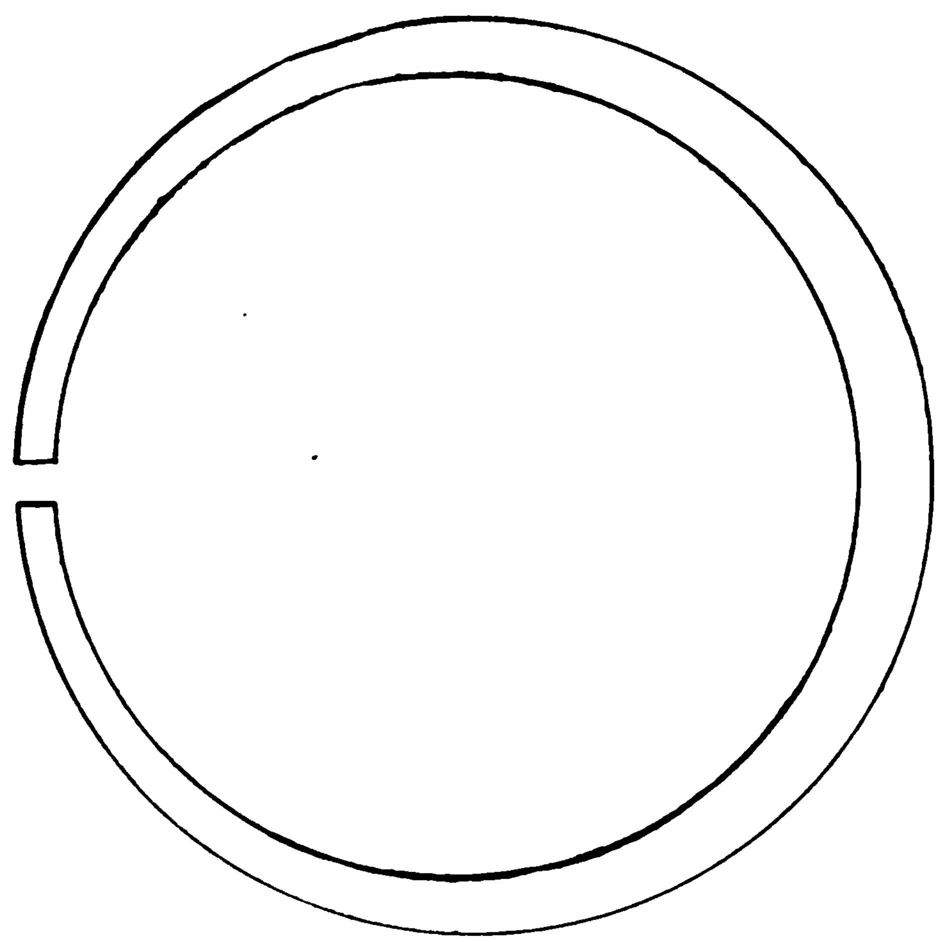


FIG. 124.—Piston Packing Ring for a Gas Engine Cylinder. The inner and outer circumferences are eccentrically arranged, so as to permit of considerable expansion under heat.

The exhaust valve is always operated mechanically from a cam-shaft; the inlet valve may be operated similarly, or may be opened by suction, created by the outward movement of the piston.

**Automatic and Positive Inlet Valves.**—The automatic inlet valve, operated by suction of the piston against the tension of a spiral spring, has been regularly used on all gas engines until very recently. The positive-operated inlet valve is now gaining favor with designers. The reasons for this change

are that the automatic valve often sticks with gummed oil on its seat; that the spring tension may vary, thus changing the fuel pressure in cylinder; that it is noisy; that its operation on high-speed engines is unreliable. As against these defects, the positive inlet valve possesses the advantages of opening and closing as desired, without noise or sticking, and of giving precisely the right pressure in the cylinder, at both high and low speeds.

**Valve Springs.**—Both valves are held to their seats by compression springs, against the tension of which they are opened.

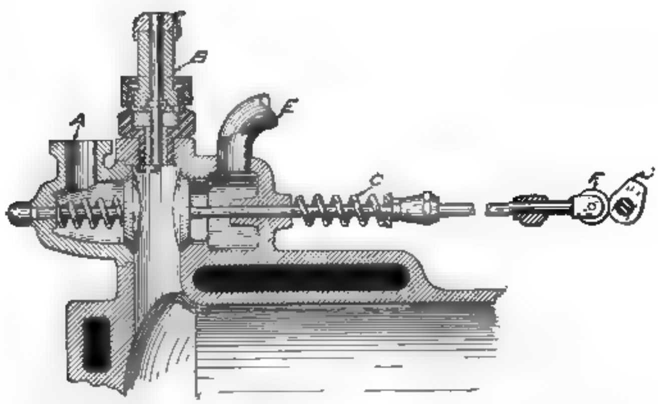


FIG. 125. Detail Diagram of the Valves and Attachments of a Gas Engine Cylinder. A is the inlet port behind inlet valve held in its seat by a tension spring; B, the spark plug for "jump-spark" ignition; C, the push rod and compression spring of the exhaust valve; D, the cam opening the exhaust; E, the exhaust port; F, the roller at end of valve rod bearing on the cam, D.

When the inlet valves are opened by piston suction, the tension of the spring is regulated, so as to give the desired initial pressure in the cylinder, as will be presently explained. The springs serve to hold the valves securely shut, when their opening is not required.

**Elements of a Vehicle Engine.**—The essential elements of a vehicle engine are:

1. The carburetter, or vaporizer, in which the liquid hydrocarbon is transformed into vapor.

2. The cylinder, to which the gas is admitted by suction, mixed with a suitable supply of pure air, compressed and ignited.

3. An ignition apparatus for producing the spark or hot surface essential to explosion.

**The Crank and Driving Gear.**—In the disposition of the crank and driving connections, the explosive motor differs radically from the common type of steam engine. The piston rod in the steam engine slides through the stuffing box in the cylinder head, and the crank is attached to the forward end at the cross head, which works between guides. The gas engine cylinder, being open at the forward end, has no head or stuffing box and no piston rod proper; in fact, the crank and piston rods are combined in one. The crank is hung on the gudgeon pin fixed midway in the length of the hollow trunk piston, and works on the crank-shaft upon which the fly-wheel is secured.

The fly-wheel is positively essential in a gas engine of any size or power. The reason for this lies in the fact that the ordinary four-cycle motor, having but one power stroke in every two revolutions of the crank shaft, requires a heavy fly-wheel to counteract the speed fluctuations and to "store up" energy sufficient to carry the rotation through the three idle strokes of exhaust, supply and compression. For this reason gas engine fly-wheels are made much heavier than those designed for steam engine use. Some one-cylinder gas and gasoline motors are made with two fly-wheels, one on either side of the crank pin, which is, in fact, attached midway on radii of the two wheels or "discs."

In several modern engines the rim of the fly-wheel is made to overhang the bearing, thus, as is claimed, securing better balance.

## CHAPTER SIXTEEN.

### THE FOUR-PART-CYCLE GAS ENGINE.

**The Cycle of a Gas Engine.**—In the practical operation of a gas engine there are several parts or stages, each characterized by a particular event. The cylinder is charged by an out-stroke of the piston, creating a vacuum behind it and drawing in the mixture of air and gasoline gas formed in the carburetter. The charge is then compressed by the return stroke of the piston, which act secures complete carburization of the contained air, and reduces the mixture to the proper condition to be kindled by the igniting spark or other source of firing. This causes it to explode, or to expand suddenly and with great effect, and drive the piston outward again. The fourth stroke, which is the one immediately following the explosion, is known as the exhaust stroke, from the fact that the piston, moving back again in the cylinder, expels the products of combustion through the exhaust valve. This process completed, the parts are in position for a repetition of the process, the valves for admitting gasoline gas to the cylinder then being opened again.

**The Four-Cycle Gas Engine.**—These four strokes—two outward and two inward—constitute the "cycle," and, as may be readily understood, there is thus only one power impulse for every two revolutions of the fly-wheel. This power stroke also continues while the crank is traveling through half a revolution, or through an arc of 180 degrees. It is also evident that the cam shaft, for operating the valve system of the cylinder, revolves but once for every two revolutions of the crank shaft, with which it is geared. Thus is secured the opening of the charging, or inlet valve, and of the scavenging, or exhaust, at precisely the proper points in the cycle. The operation of a four-cycle gas engine may be understood in figs. p. 155. Supposing we have a four-cylinder motor, the cranks of whose four pistons

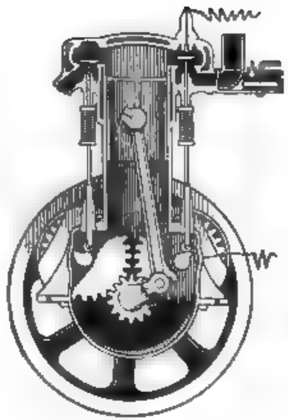


FIG. 126.

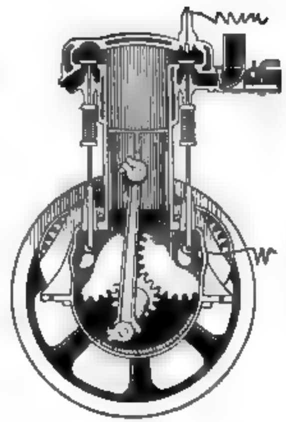


FIG. 127.

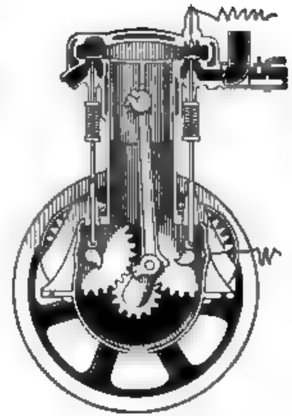


FIG. 128.

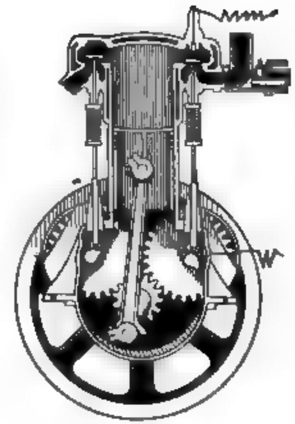


FIG. 129.

FIGS. 126-129.—Sectional Diagrams through a Single Cylinder of a Gasoline Engine, showing the four successive stages in the four-part cycle. In these diagrams both the inlet and exhaust valves are positively operated from cams on secondary shafts. The cam shafts, as shown, being on a two-to-one reduction, turn half as fast as the main shaft. Fig. 126 shows the cams and piston in the position of half way through the inlet stroke, when, as seen, the inlet valve is held open. Fig. 127 shows the beginning of the compression stroke, all valves being closed. Fig. 128 shows the engine ready for firing, all valves still closed. Fig. 129 shows the end of the firing stroke and the beginning of the exhaust, the exhaust valve being open. The view of the engine is that seen when looking toward the front of the vehicle. The fly-wheel rotates clockwise; the cam shafts counter-clockwise.

are so fixed that, counting from 1 to 4, we have pistons, cams and valves in positions representing the four cycles. That is to say, the induction, or supply stroke would be occurring in the first cylinder, the compression stroke in the second, the explosion in the third, the exhaust in the fourth. In such an engine the crank is turned by a steady impulse, since a new explosion would occur in each 90 degrees of rotation. At the aspirating or supply stroke, the outward movement of the piston, by creating a partial vacuum, causes the feed valves to open under atmospheric pressure, thus indicating that the pressure within is lower than that of the atmosphere without. At explosion the volume and temperature are raised, and at the end of the exhaust stroke the burned gases are expelled. The supply stroke being completed, and the feed valves closed by force of a spring, there is no considerable increase in volume and pressure due to contact with the hot cylinder walls, nor yet from the residuum of burnt products in the clearance, although, owing to the tension of the valve spring, the pressure of the contained gases is below one atmosphere. The rise in pressure during the supply stroke is from a negative point to generally about 13.50 pounds to the square inch. So soon, however, as the compression stroke begins, the indicator tracing shows a steady rise to 65 or 70 pounds to the square inch, at the completion of the stroke, according to the compression ratio, as will be presently explained.

At the end of the compression stroke the gas mixture in cylinder has attained its greatest density, also its greatest pressure and temperature previous to combustion. It is then ready for firing, which is generally accomplished very shortly before the piston begins the second out-stroke, the explosion serving to bring the gas to the maximum point for volume, pressure and temperature alike. In fact, the effect, as shown by thermometer and indicator tests, is that the temperature in a gas-engine cylinder rises during this stroke from between 500 and 700 degrees, absolute, as noted when the engine is running at good speed, to between 1,500 and 2,000 degrees, on the average, and the pressure from an indicated 65 or 70 pounds to 200 or 230 pounds per square inch.

The fall in both particulars is equally rapid during the succeeding in-stroke, when the burnt gases, under impulse from the piston, are expelled through the open valves.

Regarding the time of firing practice differs considerably. Generally, as stated above, it is slightly before the beginning of the power stroke, in order to allow time for the burning gas to begin expansion. Slow-speed motors are generally fired very slightly after the dead centre. With high-speed motors it varies from about 5 degrees after dead centre to 30 or 40 degrees ahead (as measured on the crank). With a large spark, hot motor and well-mixed fuel, the advanced spark is seldom set more than 15 or 20 degrees ahead.

# CHAPTER SEVENTEEN.

## THE TWO-PART CYCLE GAS ENGINE.

**The Two-Cycle Engine.**—To the present time the greater majority of hydro-carbon vehicle engines operate on the four-part cycle. There is another form of engine, however, known as the two-cycle, in which the four essential operations, charging, compression, firing, exhaust, are performed in one revolution of the fly-wheel, instead of two. The most familiar form of the two-cycle engine is that shown in the Figures 130-131-132 and its essential features are:

1. An enclosed crank case fitted with a valve arranged to open and admit fuel gas at the front, instead of at the rear of the piston, on the inward, instead of the outward stroke, as in the four part cycle.

2. Inlet and exhaust parts located at points near the extreme outward position of the piston, so as to be uncovered during the outward stroke.

3. A by-pass tube connecting the interior of the cylinder with the crank case, so as to admit fuel gas at the proper point in the cycle.

Since all the essential operations occur during a single revolution of the fly-wheel, every out-stroke of the piston is made under the stress of the exploding fuel charge in the combustion space. The ignited gas continues expanding, driving the piston outward, until the exhaust port begins opening. Exhaust then follows rapidly and is well under way when the inlet port, generally located on the opposite side of the cylinder wall, is uncovered by the outward-moving piston.

The fuel gas in the crank case is slightly compressed by the outgoing piston, and, on the opening of the inlet port, rushes

into the combustion space, being deflected upward to the rear end of the cylinder by a screen or deflector plate set in the end of the piston. The inlet of new fuel gas and the exhaust of the burned-out products of the last charge continue until the extreme end of the stroke, and during the next instroke, until the closure, first of the inlet, then of the exhaust port. From this point, the compression of the new charge begins, and on the completion of the instroke the charge is ready for ignition.

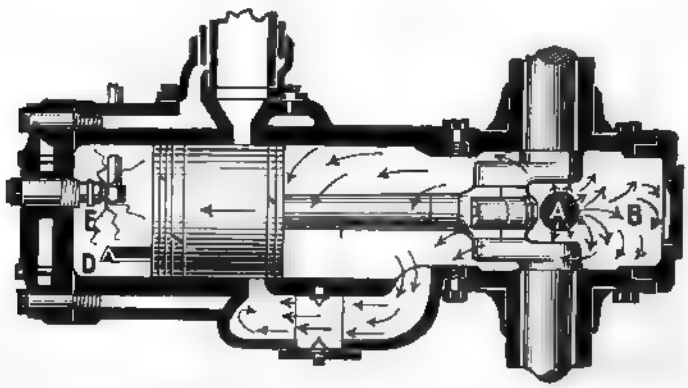



FIG. 130.—Diagram of the Two-part Cycle of a Gas Engine, I. The instroke of the piston, showing the aspiration of fuel gas at A, into crank case, B, and the spark at E in combustion space, D.

**Two-Cycle Engines for Motor Vehicles.**—Several recent makes of motor vehicle are propelled by two-cycle engines, and, according to reports yield very satisfactory results. The advantages claimed are:

1. A power stroke in every revolution of the fly-wheel for each cylinder—provided the engine has more than one—with twice the consequent power effect per cylinder, as compared with the four-cycle engine.

2. The entire absence of poppet valves, with their springs, stems, push-rods and cam-shafts; thus effecting a greater simplicity of construction and operation.

These considerations should constitute the two-cycle the ideal form of engine for motor carriage purposes. There have been,

however, several objections to its use, which, so it is claimed, have been only recently overcome. Prominent among these was the fact that the two-cycle engines, built some years since, seemed incapable of the high speeds required in motor vehicle work; realizing at best not more than between 300 and 400 revolutions, as against an average of 1,500 revolutions for the four-cycle engine, and giving only about 60 per cent. of the power at the same speed. This result was believed to follow on the fact that the cylinder would rapidly choke up with exhaust gas products, which were unable to escape when high speeds were attempted.

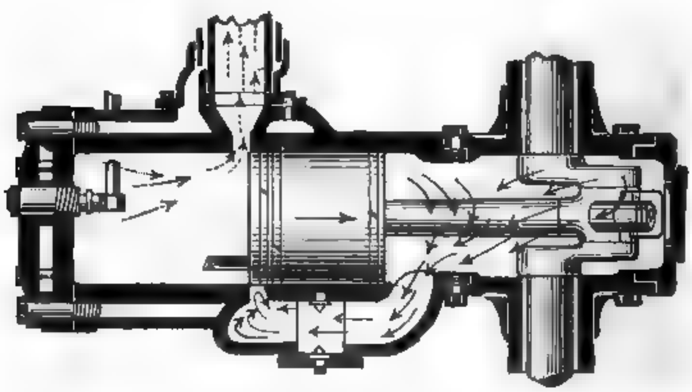


FIG. 131.—Diagram of the Two-part Cycle of a Gas Engine, II. The outstroke of the piston, showing the exhaust of the burned out gases and the compression of the fuel gas in the crank case.

As a consequence, the four-cycle engine has hitherto been considered the only available form for high speed use.

The two-cycle engine has had its widest sphere of use on motor boats, but the highest speed boats are propelled by engines of the four-cycle type. The majority of two-cycle boat engines, however, have been of one and two-cylinder patterns, which are now claimed to be inferior in speed to the four-cylinder.

**Essentials of a Two-Cycle Engine.**—A successful two-cycle vehicle engine, designed to operate at speeds at all commensurate with the four-cycle vehicle engines, must embody precisely one

feature of design, not always easy to realize—provision for rapid exhaust of the burned gases. A prominent gas-engine authority remarks: "The two-cycle engine, at best, is the next thing to an impossibility." By this statement he means that, the act of admitting inflammable fuel mixture into the cylinder, already filled with flaming gas, without igniting it, involves something closely approaching a contradiction in physical conditions. Were it not for the fact that the burning gases actually exhaust faster than the new mixture is admitted under impulse of their inherent expansion, the ignition of the new charge would seem to be nearly

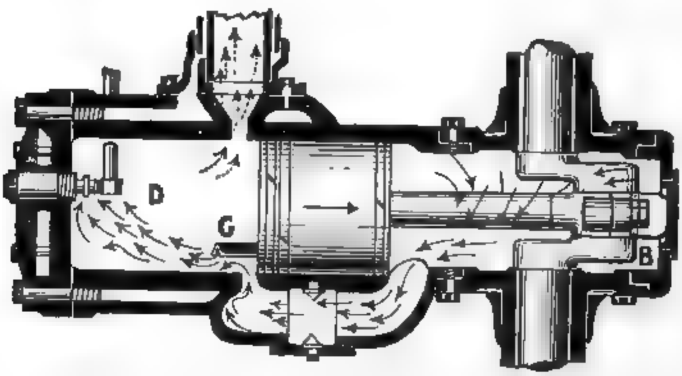



FIG. 132.—Diagram of the Two-part Cycle of a Gas Engine, III. The end of the outstroke The gases compressed in the crank case are admitted to the cylinder space, D, through the open inlet port, and past the screen or deflector, C. The passage between cylinder and crank case is controlled by a butterfly valve, which here, as in the other cuts, is shown open

inevitable. By deflecting the incoming mixture to the rear end of the cylinder, it follows the rapidly expanding exhaust, coming into contact with it only when the expansion has so far reduced the temperature that the danger of pre-ignition is averted. It may be readily seen, however, that the danger of such interference, or, at best, of a contamination of the new charge to a point rendering it unignitable must result, if the speed be increased beyond a certain moderate rate.

**The Exhaust of a Two-Cycle Engine.**—Many authorities enlarge upon the danger of exhaust gases rushing back from the

muffler into the cylinder of a two-cycle engine and producing the condition known as "choking-up" If, therefore, high speeds are to be attempted, the back-pressure of the muffler must be reduced as far as possible, and the exhaust must be rendered correspondingly rapid. These results have been variously achieved, familiarly:

1. By making the exhaust ports twice the width of the inlets, so as to allow the burned gases free egress to the muffler at a much higher speed than is achieved by the incoming mixture.

2. By arranging a rotary fan or blower to hasten the speed and volume of the exhaust, and also assist in cooling the cylinder space, as the new charge enters.

By using the latter device the speed of the engine could be very materially increased.

**Governing a Two-Cycle Engine.**—The essential features in the control of a two-cycle are a wire gauze screen in the by-pass pipe, for the purpose of preventing back-firing, or crank-case explosions, which would undoubtedly result in some cases; a butterfly valve in the by-pass, for the purposes of throttling the volume of the charge, in order to reduce the speed. The mixture may be modified by controlling the percentage of gasoline, as in other hydro-carbon engines, but the butterfly valve furnishes the most available means for ordinary control.

The use of the two-cycle engine for propelling a motor vehicle is largely limited by questions of design. It is not impossible, therefore, that it may yet be perfected for high-speed vehicle purposes.

## CHAPTER EIGHTEEN.

### THE CONDITIONS OF COMPRESSION AND EXPANSION.

**Proportionate Figures for Temperature and Pressure.**—In the operation of a gas engine, the fuel gas is confined within the cylinder, so long as it exerts an effect on power and speed. If, then, we know the total cylinder content, we have a constant standard of comparison for calculating the pressure and temperature of a given mixture of gas and air under the several conditions of the cycle. For, although the contained gas occupies the same cubic content at the beginning of the compression stroke and at the end of the firing stroke, it is obvious that its proper volume is vastly increased at the latter moment, as indicated by the raised pressure and temperature. But, following the principles laid down above, we find that the figures are regular and proportionate as between the initial and final volumes, pressures and temperatures.

**Initial and Final Figures.**—Theoretically, the operations of a gas engine accord with the general laws of gas under the influence of heat and pressure. Accordingly we speak of:

1. *The initial pressure, temperature or volume,* which belong to a gas previous to either compression or expansion. In gas-engine practice initial figures usually refer to the conditions existing at the completion of the supply or aspirating stroke of the cycle.

2. *The final pressure, temperature or volume,* which belong to a gas after either compression or expansion. If we are speaking from the standpoint of expansion the *initial* figures refer to the conditions of explosion; if, on compression, the initial figures refer to the supply stroke. In both cases the final figures refer to the changed conditions found at the end of the operation.

*The compression and explosion* figures depend upon the conditions existing at the end of the *compression stroke* and at the beginning of the *firing stroke,* respectively.

**Ratios of Figures.**—Furthermore, all these elements are related according to the following principles:

1. The final volume divided by the initial volume is equal to the final pressure divided by the initial pressure.

2. The final volume divided by the initial pressure is equal to the initial volume divided by the final pressure.

3. The final volume equals the quotient found by dividing the product of the initial pressure and initial volume by the final pressure.

4. The final pressure equals the quotient found by dividing the product of the initial pressure and initial volume by the final volume.

5. The final pressure also equals the quotient found by dividing the product of the initial pressure and final temperature by the initial temperature.

6. The final temperature equals the quotient found by dividing the product of the initial temperature and final pressure by the initial pressure.

In the following formulæ,
Let $P'$ be the initial pressure.
Let $P''$ be the final pressure.
Let $T'$ be the initial temperature.
Let $T''$ be the final temperature.
Let $V'$ be the final volume.
Let $V''$ be the initial volume.

Then, expressing these laws mathematically, we have:

$$\frac{P'\ V'}{P''} = V''; \qquad \frac{P'\ V'}{V''} = P'';$$

$$\frac{P'\ T''}{T'} = P''; \qquad \frac{T'\ P''}{P'} = T''.$$

As previously suggested, definite figures for all these elements may be found only when the cubic content of the cylinder is known. The cubic content of the stroke and clearance areas may,

of course, be calculated, when the inside diameter and length of the cylinder and length of the stroke are known. A more practical method suggested by Roberts is to turn the crank to the backward dead centre, close the valves, and fill the cylinder with water. By altering the position of the crank from in-stroke end to out-stroke end, the cubic content of both clearance and total cylinder, including stroke sweep, may be accurately estimated. The water having been weighed before pouring it into the cylinder, the weight of that left over is a ready indication of the weight of that within.

This latter method is particularly convenient where the cylinder has a spherical or enlarged combustion chamber, which would involve mathematical processes of considerable intricacy to estimate its content in cubic feet.

At 39.1° Fahrenheit water weighs 62.5 pounds per cubic foot. When the water is at a higher temperature, its weight per cubic foot may be found by the following formula, in which T is the temperature shown by thermometer; 461, the constant of absolute temperature, and 500, the absolute temperature of water at 39.1 degrees.

$$\frac{62.5 \times 2}{\frac{T + 461}{500} + \frac{500}{T + 461}} = \text{Weight per cubic foot.}$$

Here we need only substitute the ascertained temperature figures for T wherever it occurs, reduce the fractions to a common denominator, and perform the indicated additions and divisions.

**Measuring the Conditions of Operation.**—The factors entering to vary the figures, with the same initial pressures in different engines, are the ratio of compression and the percentage of the clearance volume, as compared with the total cylinder volume.

**The Ratio of Compression.**—The ratio of compression is found to be equal to the quotient of the total volume of the cylinder from the beginning to the end of the stroke, including also the clearance, divided by the volume of the clearance, which, as is evident, is never decreased during any portion of a stroke.

Applying the rule for calculating the compression ratios of two cylinders, in which the clearance and total content are in proportion of 2 to 4 and 1 to 4, respectively, we derive the following expressions:

$$\frac{2+4}{2} = 3 \qquad \frac{1+4}{1} = 5$$

**The Percentage of Clearance.**—The percentage of the clearance volume is similarly found by dividing the volume of the clearance by the volume of the piston displacement.

In other words, it is the quotient of the cubic content of the clearance (from the rear of the cylinder to the rearmost reach of the piston at the end of an in-stroke), divided by the cubic content of that portion of the cylinder included between the inmost point of the in-stroke and the outmost point of the out-stroke, as indicated by the position of the rear end of the piston at those two points.

Taking the same two cylinders, having, respectively, clearances of 2 cubic feet and 1 cubic foot, and stroke-sweeps of 4 cubic feet, both, we find the clearance percentage, as follows:

$$\frac{2}{4} = .5 \text{ or } 50\%. \qquad \frac{1}{4} = .25 \text{ or } 25\%.$$

**The Compression Pressure.**—In order to find the pressure per square inch at the end of the compression stroke, it is necessary only to multiply the figure corresponding to an engine with the given compression ratio and percentage of clearance by the ascertained gauge pressure at the beginning of the stroke, or any other required pressure at the same point. Thus the initial pressure at theoretical unity for a cylinder having a compression ratio of 3 and a clearance percentage of 50 is 4.407, which, multiplied by 13, the gauge or desired pressure, gives 57.29; by 13.2, gives 58.17; by 13,5, gives 59.49; by 14, gives 61.69; by 14.7, gives 64.78.

**The Compression Temperature.**—The compression temperature is similarly determined by multiplying the found or required absolute temperature at the beginning of the stroke by the figure for one degree for a type of engine having the same compression ratio as the one in question. Thus, for an engine having the ratio

***Table for Calculating the Compression Pressure and Temperature of a Gas Engine.***

| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| 3. | .4771213 | 50. | 4.407 | 4.264 | 146.89 | 142.13 |
| 3.05 | .4842958 | 48.78 | 4.506 | 4.358 | 147.74 | 142.88 |
| 3.1 | .4913617 | 47.62 | 4.606 | 4.452 | 148.58 | 143.62 |
| 3.15 | .4983106 | 46.51 | 4.707 | 4.547 | 149.42 | 144.36 |
| 3.2 | .50515 | 45.45 | 4.808 | 4.643 | 150.25 | 145.10 |
| 3.25 | .5118834 | 44.44 | 4.910 | 4.739 | 151.06 | 145.82 |
| 3.3 | .5185139 | 43.48 | 5.011 | 4.835 | 151.87 | 146.53 |
| 3.35 | .5250448 | 42.55 | 5.115 | 4.932 | 152.67 | 147.23 |
| 3.4 | .5314789 | 41.66 | 5.217 | 5.030 | 153.47 | 147.93 |
| 3.45 | .5378191 | 40.82 | 5.322 | 5.128 | 154.25 | 148.63 |
| 3.5 | .544068 | 40. | 5.426 | 5.226 | 155.03 | 149.32 |
| 3.55 | .5502284 | 39.22 | 5.531 | 5.325 | 155.80 | 150. |
| 3.6 | .5563025 | 38.46 | 5.637 | 5.424 | 156.57 | 150.66 |
| 3.65 | .5622929 | 37.74 | 5.742 | 5.524 | 157.32 | 151.33 |
| 3.7 | .5682017 | 37.04 | 5.848 | 5 624 | 158.08 | 151.99 |
| 3.75 | .5740313 | 36.36 | 5.956 | 5.724 | 158.82 | 152.65 |
| 3.8 | .5797836 | 35.71 | 6.064 | 5.825 | 159.56 | 153.30 |
| 3.85 | .5854607 | 35.09 | 6.171 | 5.927 | 160.29 | 153.94 |
| 3.9 | .5910646 | 34.48 | 6.280 | 6.029 | 161.02 | 154.57 |
| 3.95 | .5965971 | 33.9 | 6.389 | 6.131 | 161.73 | 155.21 |
| 4. | .60206 | 33.33 | 6.498 | 6.233 | 162.45 | 155.83 |
| 4.1 | .6127839 | 32.26 | 6.718 | 6.440 | 163.86 | 157.07 |
| 4.2 | .6232493 | 31.25 | 6.940 | 6.648 | 165.25 | 158.28 |
| 4.3 | .6334685 | 30.3 | 7.164 | 6.858 | 166.62 | 159.48 |
| 4.4 | .6434527 | 29.41 | 7.390 | 7.069 | 167.96 | 160.66 |
| 4.5 | .6532125 | 28.57 | 7.618 | 7.282 | 169.29 | 161.82 |
| 4.6 | .6627578 | 27.77 | 7.847 | 7.496 | 170.59 | 162.96 |
| 4.7 | .6720979 | 27.03 | 8.078 | 7.712 | 171.88 | 164.09 |
| 4.8 | .6812412 | 26.32 | 8.311 | 7.929 | 173.15 | 165.20 |
| 4.9 | .6901961 | 25.64 | 8.546 | 8.148 | 174.41 | 166.29 |
| 5. | .69897 | 25. | 8.783 | 8.368 | 175.64 | 167.37 |
| 5.1 | .7075702 | 24.39 | 9.020 | 8.590 | 176.87 | 168.43 |
| 5.2 | .7160033 | 23.81 | 9.260 | 8.813 | 178.07 | 169.48 |
| 5.3 | .7242759 | 23.25 | 9.501 | 9.037 | 179.26 | 170.52 |
| 5.4 | .7323938 | 22.73 | 9.744 | 9.263 | 180.44 | 171.54 |
| 5.5 | .7403627 | 22.22 | 9.988 | 9.490 | 181.60 | 172.55 |
| 5.6 | .748188 | 21.74 | 10.234 | 9.719 | 182.75 | 173.55 |
| 5.8 | .763428 | 20.83 | 10.73 | 10.180 | 185.01 | 175.50 |
| 6. | .7781513 | 20. | 11.233 | 10.646 | 187.22 | 177.42 |

Column A gives the compression ratio of the cylinder; column B the logarithm of the compression ratio; column C the per cent. of clearance corresponding to any given compression ratio.

Column D gives the figures for the compression pressure corresponding to a theoretical one-pound initial pressure. The figures in this column, corresponding to any given compression ratio, if multiplied by the initial pressure in that cylinder (14.7 minus resistant strength of inlet valve spring), will give the proper compression pressure corresponding to the initial pressure for that cylinder.

Similarly, column E gives the compression pressure corresponding to a theoretical one-pound initial pressure for a scavenging cylinder, whose proper compression pressure may be found by multiplying by the initial pressure.

Columns F and G give the compression temperature for a plain and a scavenging cylinder, respectively, corresponding to a theoretical 100-degree absolute initial temperature. The proper compression temperature for a cylinder of given per cent. clearance and compression ratio may be found by multiplying the figures in either of these columns by $\frac{1}{100}$ of the ascertained absolute compression temperature in the plain or the scavenging cylinder in question. Table from *Power*.

of 3, the theoretical initial temperature is estimated as 1.46°, which, for an initial absolute temperature of 525° (64° + 461) gives 766° (305° + 461), and for 560° (99° + 461) gives 822° (361° + 461).

**High Compression and Efficiency.**—Other things being equal, it might seem reasonable to assert that, the higher the pressure of compression, the greater the rise in temperature at the point of ignition, and, consequently, the greater the power efficiency of the engine. In accordance with this view, we find that, while in many early gas engines the compression pressure was very much below 50 pounds to the square inch, with the more modern and improved patterns it strikes an average in the neighborhood of 70 pounds.

It must not be forgotten, however, that this rule has very definite limitations, and that beyond a certain point of increased compression pressure the efficiency ratio begins to decrease rapidly. This is true, because, although a gas is generally more explosive under pressure, there is always a point at which the rule begins to change. Again, the practical reason, that, to produce a higher compression, a greater amount of power must be absorbed, renders the limitations still more obvious.

**High Compression Figures.**—Taking a theoretical one-pound pressure and one-degree temperature initial, we have the following figures for varying compression ratios in non-scavenging engines, derived as above:

With a ratio of 3, we have 4.407 for pressure and 1.4689 for temperature; with 4, we have 6.498 and 1.6245, respectively; with 5, we have 8.783 and 1.7564; with 6, in the same way, 11.233 and 1.8722. These figures, multiplied by the ascertained initial pressure and temperature in any particular engine of the same ratio, will give the proper figures for that engine.

**Data on Compression Pressure.**—On the matter of compression figures this quotation from Hiscox will suffice:

"It has been shown that an ideal efficiency of 33 per cent. for 38 pounds compression will increase to 40 per cent. for 66 pounds, and 43

per cent. for 88 pounds compression. On the other hand, greater compression means greater explosive pressure and greater strain on the engine structure, which in future practice will probably retain the compression between the limits of 40 and 60 pounds.

"In experiments made by Dugald Clerk with a combustion chamber equal to 0.6 of the space swept by the piston, with a compression of 38 pounds, the consumption of gas was 24 cubic feet per indicated horse-power per hour. With 0.4 compression space and 61 pounds compression, the consumption of gas was 20 cubic feet per indicated horse-power per hour; and with 0.34 compression space and 87 pounds compression, the consumption of gas fell to 14.8 cubic feet per indicated horse-power per hour—the actual efficiencies being respectively 17.21 and 25 per cent. This was with a Crossley four-cycle engine."

**Rate of Gas Consumption.**—As given by several authorities, who base their calculations upon the performance of engines operating under favorable conditions, and using the fuel best suited to the end in view, the average of gas consumption per horse-power hour is 20 cubic feet, although, as may be readily understood, such figures vary with the kind and quality of fuel and in other proportions, as mentioned by Hiscox. There are, however, other considerations entering into the judgment of ideal efficiency, and some of these we will proceed to treat.

# CHAPTER NINETEEN.

## OPERATION AND EFFICIENCY IN A GAS ENGINE.

**Definition of Efficiency.**—The efficiency of a gas engine is the "ratio of heat turned into work, as compared with the total heat produced by combustion."

**The British Thermal Unit.**—The comparison of heat and work in this particular is based upon the *amount, rather than upon the degree,* of heat used. The standard is the so-called *British Thermal Unit,* which may be defined as the amount of heat capable of raising one pound of water through one degree Fahrenheit. This is not a mere question of thermometric temperature. An alcohol lamp and a locomotive furnace may register the same degree on the scale, but the lamp would require a longer period to accomplish the above result—in other words, to generate one thermal unit.

**The Efficiency Ratio.**—Since all the heat generated by combustion of the gas in cylinder can positively not be utilized as mechanical energy, the efficiency of a gas engine is expressed as a ratio or a fraction. Thus, an engine giving an efficiency of 20 out of each 100 heat units generated would have an efficiency of 20-100ths, or 20 per cent.

**The Mechanical Efficiency.**—The mechanical efficiency of a heat engine must necessarily be far below the actual heat generated, even with the most perfect machinery imaginable, since it seems practically impossible to fully realize theoretical conditions. Thus, in the operation of a heat engine, there must necessarily be some loss or gain of heat as the gas expands. This, of course, modifies the curve of expansion, and involves a lower mean pressure than is theoretically demanded, should at any time be available for power effort. No expansion in a

practical heat engine is perfectly adiabatic; involving that the mean working pressure is always below that required by theory.

**The Conditions of Efficiency.**—The efficient power of a gas engine is not dependent wholly, or even largely, on relative proportions among the working parts, and, at most, the figures given above are averages for the best obtainable conditions. These conditions are found to consist principally:

1. In the use of the best qualities of fuel.
2. In the production of the best proportions of mixture in fuels.
3. In conditions and means, favorable to rapid and complete ignition of the charge.
4. In efficient means for cooling the cylinder.

**Conditions of Fuel Combustion.**—In order to secure the proper degree of power efficiency, it is important to consider:

1. Proportioning fuel mixture, since too much or too little of either air or hydrocarbon gas produces the effect of weak or imperfect explosion of the charge.
2. Provision for adequate compression of the charge, in order that, despite the presence of the burned and exhausted gases of previous combustions, there may be uniformity of mixture throughout the mass of fuel gas in cylinder. This is an important element in securing rapid and effective ignition.

**The Theory of Fuel Mixtures.**—All oils and spirits may be ignited and burned if heated to the required temperature, differing in each case, provided at the same time that air can circulate freely where the heating takes place. The air is required, in order to furnish a sufficient quanity of oxygen for combustion, which, properly speaking, is only the chemical process of absorbing oxygen. The temperature at which an oil or spirit gives off inflammable vapors is called the *flash point*, and the point at which it may be ignited and burned is called the *fire point*. Without a sufficient quantity of air, however, no liquid will either flash or fire, even if confined in a closed vessel heated to very high temperature.

In order to illustrate, the following list of several hydrocarbons, together with their flash and fire points, is quoted from a well-known authority:

| | Flash Point. | Fire Point. |
|---|---|---|
| Commercial brandy | 69 | 92 |
| " whiskey | 72 | 96 |
| " gin | 72 | 101 |
| Kerosene (average quality) | 73 | 104 |
| Petroleum (high test) | 110-120 | 140-160 |

**Proportions of Fuel Mixtures.**—In the open air the only point to be considered is the temperature for flashing or firing, since atmospheric circulation will always supply the full amount of oxygen for combustion. In a gas-engine cylinder, closed from the outer air, it is necessary to know how much air must be admitted. The most efficient proportions of air and gas, mixed to give a perfect combustion in a closed cylinder, may be considered a matter in many respects relative to the kind of gas employed—some gases require more, some less, for the best effects from combustion.

**Figures for Coal Gas.**—In general, however, the data on coal gas may be taken as typical for most fuels available in ordinary gas-engine service. With this fuel the figures for good efficiency range between 6 to 1 and 11 to 1 for air and gas, respectively. That is to say, with a mixture of about 5 to 1 or about 12 to 1, for example, the effective pressure due to combustion—if combustion is possible at all—shows a marked falling off, which continues thereafter as the proportion of air in the mixture is either diminished or increased.

**Effects of Varying Mixtures.**—Between the efficient extremes it has been found that, although the actual indicated explosion pressure decreases in ratio with the increased percentage of air in the mixture, the efficiency steadily increases until the point of 11 to 1 is approximated. This fact is explained by assuming that, in increasing the proportion of air in the mixture, the temperature per unit of gas is raised, although the temperature per

unit of the mixture of gas and air is lowered. Since, therefore, the gas itself is the sole agent of efficiency—the condition necessary to explosion being all that is furnished by the admixture of air—the increase in the proportion of air in the charge, up to the specified limit, increases the total efficiency, even though lowering the pressure of the explosion.

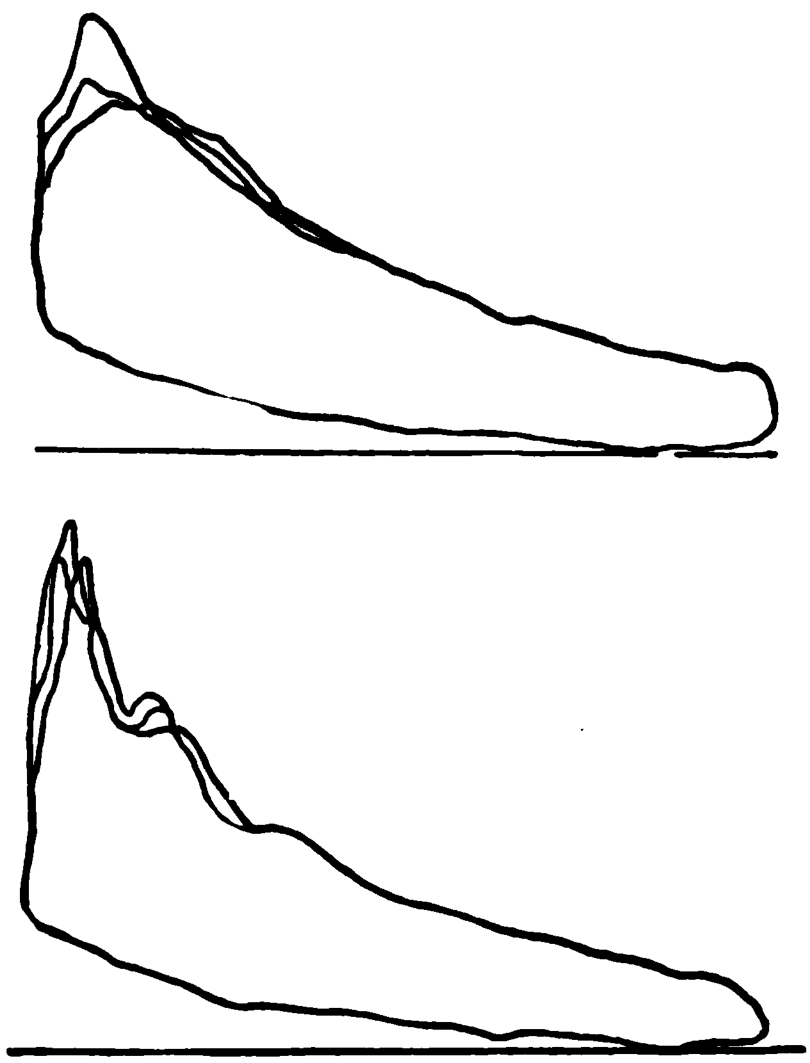


FIG. 133.—Typical Gas-Engine Indicator Cards, taken under actual service conditions. The first diagram is from an engine running under half load; the second from one at full load. Both exhibit the variations in the expansion curve, usually attributed to consecutive explosions. These cards are composites of three successive strokes each.

**Causes of Defective Mixture.**—As already suggested, an adequate degree of compression is as essential to perfect efficiency in a gas engine, from the fact that a more complete mingling of the fuel ingredients is thus secured. In the same engine, however, as shown by indicator cards, several successive firing strokes will show a marked variation in the pressure rise at explosion. Some authorities refer this to the presence of residual burned-out gases in the clearance, which tend to *stratify* the fuel, producing layers of incombustible gas, with the result that several successive weak explosions occur instead of one full and complete explosion.

**Advantages of Scavenging.**—That the presence of non-combustible burned gases in the cylinder clearance is a fertile source of lost efficiency seems proved by the superior average performance of scavenging engines, in which these residue are largely expelled.

"A mixture of 9 to 1, with no burned gases present, gives a rise of about 2,373 degrees; the same mixture, compressed with the burned gases of a previous explosion in a clearance of 41 2-3 per cent. of the cylinder volume gives a rise of only about 1,843 degrees.

"The resulting temperatures of explosion in the two cases do not differ so greatly as the rise in temperature, because the scavenging engine starts from a lower initial temperature and the rise during compression is not so great. For example, assume an engine with 3.4 compression ratio, running scavenging with an initial pressure of 13.2 pounds and an initial temperature of 580 degrees; and suppose a similar engine running plain, with 13.2 pounds initial pressure and 600 degrees initial temperature. The results are compared below on the basis of a 9 to 1 mixture:

| | Ordinary. | Scavenging. |
|---|---|---|
| Initial temperature | 600 | 580 |
| Compression temperature | 921 | 858 |
| Rise in temperature by explosion | 1,843 | 2,373 |
| Temperature of explosion | 2,764 | 3,231 |

"In this comparison the difference in the rise of temperature is nearly 29 per cent. while the difference between the explosion temperatures of the two engines is only scant 17 per cent. A better comparison may be had by considering the pressures; these figure out as follows:

| | Ordinary. | Scavenging. |
|---|---|---|
| Initial pressure | 13.2 | 13.2 |
| Compression pressure | 68.86 | 66.4 |
| Explosion pressure | 206.65 | 250.0 |

"Thus, the scavenging engine shows a maximum temperature about 17 per cent. higher than the other engine, while its maximum pressure is a trifle over 21 per cent. greater. * * * * * While excessive explosion pressures are not desirable, it is clearly advantageous, within practical limits, to increase the difference between the maximum forward pressure and that of compression, because it increases the area of the indicator diagram. And as this result is obtained by scavenging, without consuming any more gas, the superiority of a scavenging engine is obvious."

## CHAPTER TWENTY.

### THE EXHAUST OF A GAS ENGINE.

**Losses in the Exhaust.**—In the operation of a gas or gasoline engine a large amount of heat and power units are inevitably lost in the exhaust.

The principal reason why this loss may not be avoided is that the gas, after explosion, may not be expanded to atmospheric pressure within the cylinder. At the completion of the power stroke the expansion line stands generally about or above the figure indicated for compression pressure. It is necessary, therefore, to open the exhaust before the completion of the stroke, generally at about $\frac{7}{8}$ stroke. Were the engine otherwise geared, and the piston allowed to receive the pressure of the expanding gas through its full stroke, the gas would not exhaust fast enough to avoid buffing the piston on its return sweep, since through an appreciable distance the continued expansion would balance the rate of escape through the exhaust valve. The effect of this would be to check the speed and power of the engine, with the result of absorbing about as much power as would on the other plan be turned to waste.

**The Variation of the Curve of Expansion.**—The expansion following explosion is not instantaneous, but continues throughout the stroke, thus constantly keeping up the temperature and pressure, which would, otherwise, tend to fall regularly from maximum to atmosphere. Thus the expansion line on the indicator diagram does not meet the compression line at the end point of the stroke, as should be the case under theoretically perfect conditions. Consequently the exhaust valve must be opened before the completion of the stroke, as above stated.

**The Ratio of Expansion.**—As may be readily understood, the practice of opening the exhaust valve at about $\frac{7}{8}$ power stroke

involves that the expansion ratio differs greatly from the compression ratio, with which, theoretically, it should be identical.

The expansion ratio represents the quotient found by dividing the sum of the total cylinder content (clearance + piston sweep) and that portion of the stroke and clearance content left behind the piston at the moment the exhaust opens, by the cubic content of the clearance. This may be expressed by the following formula:

$$Er = \frac{C + \frac{n}{c}}{B} = \frac{\text{Volume of Expansion}}{\text{Volume of Clearance}}$$

in which Er is the ratio of expansion.

C " the total cylinder content.

B " the combustion chamber or clearance content.

n " the numerator expressing the portion of the cylinder content left behind the piston at the opening of the exhaust, which, as already stated, is generally $\frac{7}{8}$ stroke length, or $\frac{7}{8}$ sweep content in cubic measure.

**Figures for Exhaust Losses.**—The pressures and temperatures voided in the exhaust are in proportion, first place, to the figures realized in explosion, and, secondly, to the expansion ratio of the particular cylinder under test. Both are found to decrease with increasing ratios. Thus, under ordinary conditions, with engines driven by illuminating gas, an explosion temperature of 3,000 and an explosion pressure of 250 for a ratio of 3 give an exhaust temperature of 2,158 and an exhaust pressure of 59.9; for a ratio of 3.5 they give 2,060 and 49.0; for a ratio of 4 they give 1,979 and 41.2; for a ratio of 5 they give 1,851 and 30.8; for a ratio of 6 they give 1,752 and 24.3.

Suppose we assume an expansion ratio of 5.8 in order to get a great expansion, and a compression ratio of 6. Then assume an ordinary engine, because the effect of explosion is not so great and a mixture of 12 volumes of air to 1 of gas, because that is the weakest reliable mixture. Starting with the highest practical initial temperature, 660 degrees, and the lowest practical initial pressure, 13, the following results are obtained:

| | Pressure. | Temperature. |
|---|---|---|
| Initial | 13 | 660 |
| Compression | 146 | 1,236 |
| Rise | 207 | 1,755 |
| Explosion | 353 | 2,991 |
| Exhaust | 35.9 | 1,765 |

**The Muffler or Silencer.**—The exhaust from the cylinder, being commonly expelled at a pressure between two and three times an atmosphere, would naturally make considerable noise and raise dust, were it not for the use of an apparatus called the muffler, or silencer. Although constructed on various designs, the muffler always involves the same theory of "breaking up"

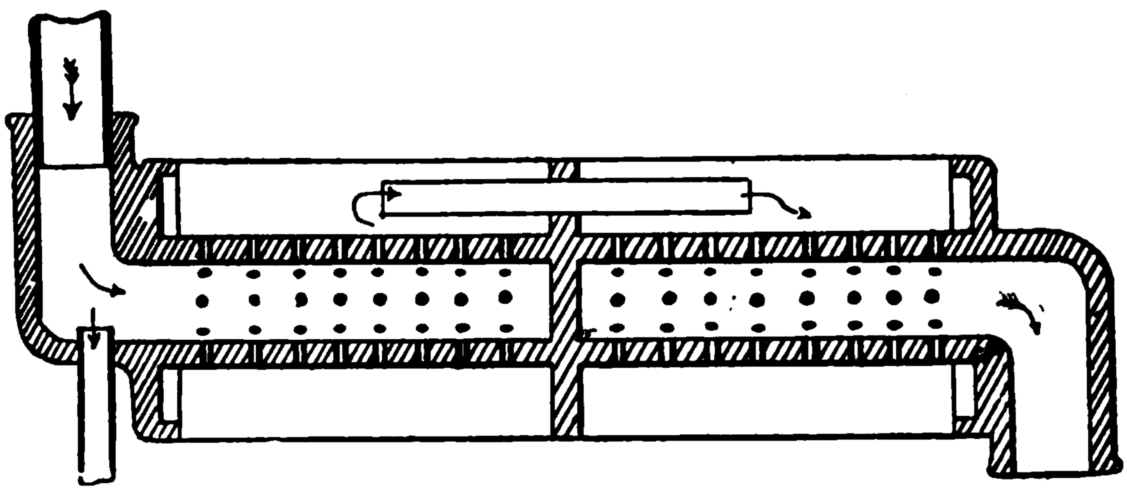


FIG. 134.—The Benz Exhaust Muffler. The arrows indicate the course of the expanding exhaust products. Entering at the left, they pass through the perforations in the tube; thence through the smaller tube in the larger chamber; again through the perforations in the right-hand section of the tube, and to atmosphere. The breaking-up of the gas in expansion silences the noise of its exhaust to atmosphere.

the exhaust gas by causing it to pass through fine perforations in the exhaust tube, and of allowing it to expand to nearly atmospheric pressure in one or several successive chambers. Several efficient types of muffler are shown in accompanying diagrams.

**Cubic Content of a Muffler.**—As indicated by Roberts, the formula for the cubic content of a muffler best calculated to save power gives 3.5 times the square of the cylinder diameter in inches multiplied by the length of the piston stroke in inches, or

$$M = 3.5\ D^2L.$$

If, therefore, a cylinder have a diameter of $4\frac{1}{2}$ inches and a stroke of 5 inches, we have:

$$M = 3.5 \times (4.5)^2 \times 5 = 3.5 \times 20.25 \times 5 = 354.375 \text{ cu. in.}$$

If two cylinders of this size exhaust into the same muffler, the cubic content should be increased by 50 per cent.; if three cylinders, by 150 per cent.; if four cylinders, by 200 per cent. In other words, under these several conditions, the muffler should be increased by one-half, once and one-half and twice the proper content for a single cylinder.

**Losses in the Muffler.**—Since, as stated, the principle of a muffler involves imposing obstacles, in the shape of minute perforations, etc., to the free expansion of exhaust gases, it furnishes a large and undesirable back-pressure.

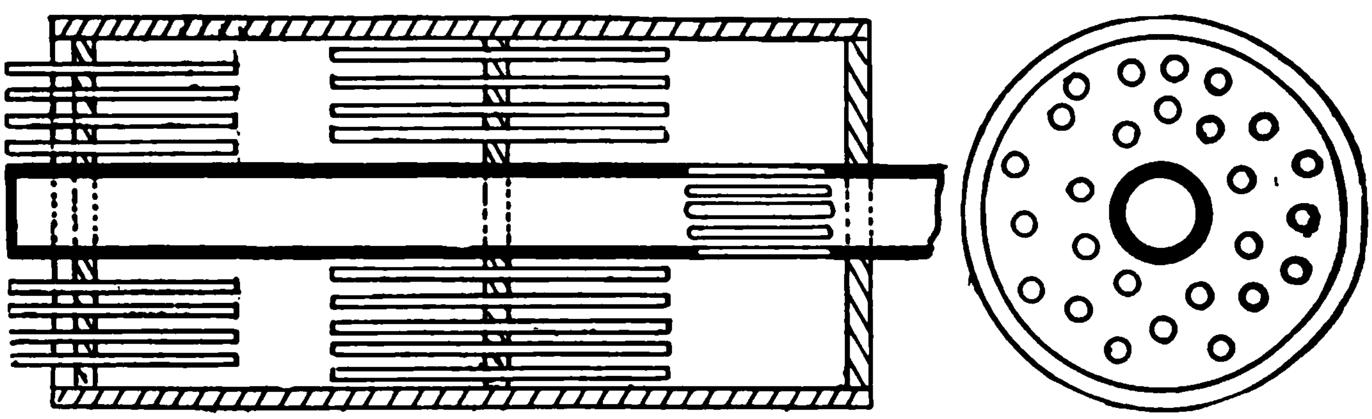


FIG. 135.—The "Loomis" Muffler. The exhaust enters the central tube at the right-hand end, passing out through slits shown in its side to the main chamber, where it is passed through a number of lengths of tubing. Leaving these it emerges to atmosphere through another set of tube lengths.

A French authority states that an engine of 8 I. H. P., running without muffler, gave 6.1 B. H. P. at 967 revolutions per minute, but with muffler gave the same efficiency only on 1,012 revolutions. He also found for a 2.25 I. H. P. engine an efficient output of 2.16 at 2,015 revolutions without muffler, and of 1.91, at 2,057 revolutions with muffler, claiming a loss of 20 kilogram-meters, or 145 foot pounds per second.

These figures are fairly typical for very many mufflers, and, although possibly reduced by some of the more modern models, represent fairly well the kind of obstacles obtruded in the way of the highest mechanical efficiency of the average gas engine.

**Preventing Exhaust Losses.**—The enormous waste, as indicated by the figures given above, which show that, with average

exhaust temperature of 1,760° absolute, or 1,300° F., escaping into an average atmospheric temperature of 70° F., (1.23 × .26) 319.8 heat units, or (319.8 × 778) 248,804 foot-pounds, or over 7.5 horse-power per pound of fuel gas goes through the exhaust valves, is a good argument for seeking some device to utilize at least a part of this lost energy.

**Cut-Out Mufflers.**—Although there have been many notable improvements, in both the design and operation of mufflers, within the last few years, the situation remains substantially the same in regard to the percentage of power lost in the exhaust.

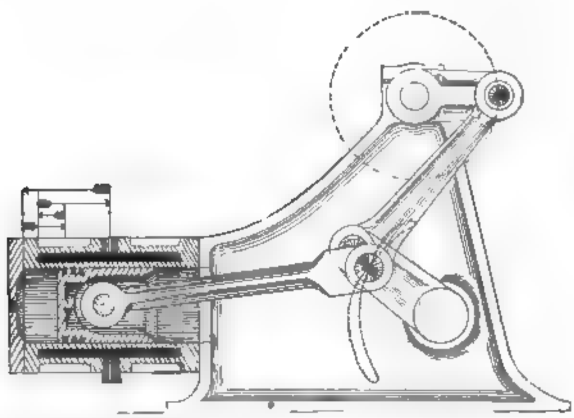


FIG. 186.—Section of the Atkinson Cycle Gas Engine, showing the varying lengths of the strokes—from the top, exhaust, expansion, compression, suction; also, the figure-of-8 path described by the toggle-jointed crank connections, and the path of the crank.

As already stated, it is impracticable to expand the ignited gas to atmospheric pressure; hence at least 16 per cent. of the total heat energy is inevitably lost on this score. Furthermore, if a muffler is to discharge its function of "muffling," or silencing, the exhaust, some back-pressure is unavoidable. Several manufacturers of mufflers confidently claim that their inventions produce "no back-pressure whatever." It would seem that their mufflers seldom get upon high-powered, high-speed cars, which in racing, and speeding on tour are commonly driven with the muffler cut out—their drivers being willing to endure the deton-

ations of the exhaust, for the sake of the additional power and mileage capacity. Many mufflers are equipped with a special cut-out attachment, which is used at starting to remove back-pressure as well as in speeding. On a 40-horse-power car as much as 6 horse-powers may be saved by the muffler cut-out.

**A Variable-Stroke Engine.**—An interesting approximation of theoretical efficiency is found in the Atkinson cycle scavenging engine, which proved able to expand the charge from 185 pounds

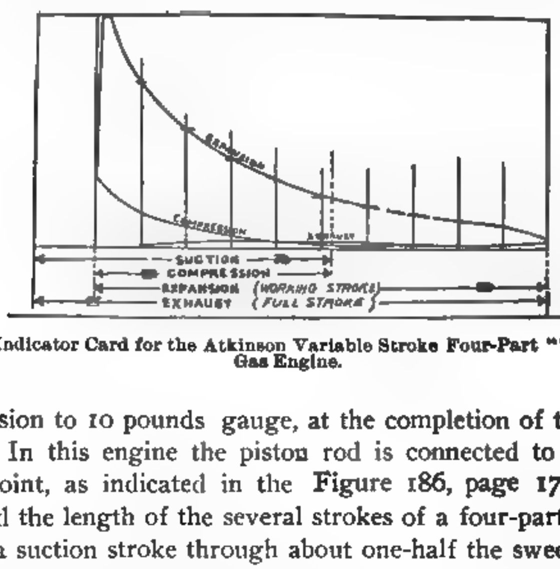



**Fig. 187.—Indicator Card for the Atkinson Variable Stroke Four-Part "Two-Cycle" Gas Engine.**

at explosion to 10 pounds gauge, at the completion of the power stroke. In this engine the piston rod is connected to a double toggle joint, as indicated in the Figure 186, page 179, which so varied the length of the several strokes of a four-part cycle, as to give a suction stroke through about one-half the sweep length, a return compression stroke to a point about 5-6 the sweep, an impulse stroke from that point clear forward, and an exhausting stroke from end to end of the cylinder. As claimed in a published description, the working effects are that

"The clearance space beyond the terminal exhaust position of the piston is so small that, practically, the products of combustion are entirely swept out of the cylinder during the exhaust stroke, so that each incoming charge has the full explosive strength due to the mixture used."

The accompanying indicator card of an Atkinson engine, of 18 I. H. P., working at 130 revolutions per minute, with a mean

pressure of 49 pounds, shows the excellent results achieved by thus varying the length of the several strokes. But such a procedure is impossible in the ordinary four-cycle engine, which finds the only available method of securing approximately complete combustion in varying proportions of the fuel mixture and by scavenging the cylinder.

Although the complications of the Atkinson engine proved it difficult to handle for stationary purposes, there can be no doubt but what it furnishes the elements of an ideal automobile motor, as will doubtless be some day realized.

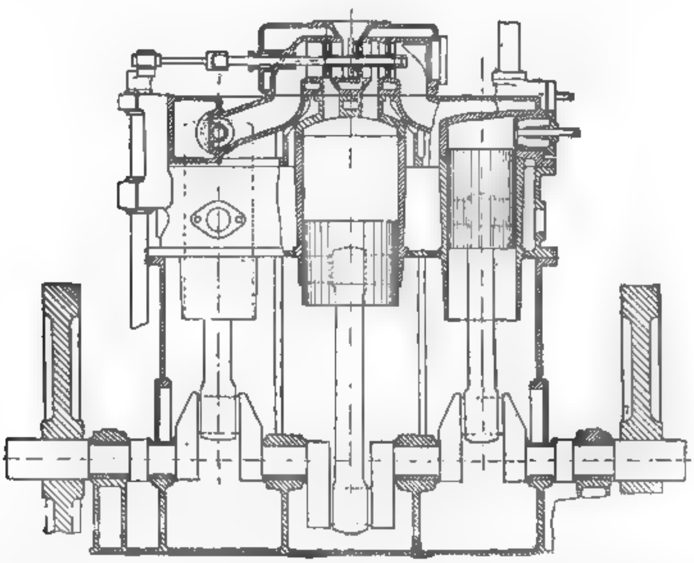


FIG. 138.—Crossley Three-Cylinder Compound Gas Engine. The two end cylinders are high pressure; the central one, low pressure. The exhaust from the two high-pressure cylinders is admitted, alternately, to the low-pressure cylinder by the piston valve, operated by the crank and rotating shaft shown at the left. The exhaust from the low-pressure cylinder passes upward through the port at its top.

**Compound Gas Engines.**—Compounding for gas engines cylinders has been proven an efficient means for utilizing the common waste of the exhaust. The accompanying figure of the Crossley & Atkinson compound gas engine shows three cylinders—two primary, or high-pressure, between which is a secondary,

or low-pressure. The cubic content of the low pressure cylinder is about twice that of either of the high pressure cylinders, thus allowing the exhaust gas to expand very nearly to atmospheric pressure, when fed into it from either of the others. The crank shaft is so arranged that, while the two low pressure pistons are at the dead end of the in-stroke—the one, of compression, the other, of exhaust, for example—the low pressure piston is at the dead end of its out-stroke, or power-stroke. Thus the exhaust gas is fed to the low pressure cylinder from both the high pressure cylinders alternately, and performs a power-stroke once in each revolution of the fly-wheel, always alternately to either of the others. As may be seen from examination of the drawing, connection between the high pressure and low pressure cylinders is had by means of a triple piston valve moved longitudinally on a secondary shaft and so arranged that pure atmospheric air may be admitted to the centre cylinder, when either of the others misses fire.

## CHAPTER TWENTY-ONE.

### WATER-COOLING FOR THE CYLINDER.

**Water-Cooling for Cylinders.**—By the far the greater proportion of gas engines—those employed alike for general power purposes and in propelling motor vehicles—have water-cooled cylinders, the water for this purpose being admitted to a jacket or water space cast around the cylinder's circumference This water circulates between the jacket space and the feed tank, either:

1. *By gravity,* in accordance with the laws of liquids, which cause the heated layers to rise from the bottom to the top of the reservoir, and the cooler layers to fall correspondingly.

2. *By forced circulation,* under impulse from a rotary or centrifugal pump, which keeps the water in constant motion.

**Air-Cooling for Cylinders.**—In recent years air-cooling for automobile engine cylinders has been successfully achieved in a variety of ways:

1. By providing a sufficiently large radiating surface by means of cast flanges or gills, inserted pins and tubes.

2. By using unusually large exhaust valves, so as to cool the combustion space between power strokes.

3. By combining large radiating surfaces with low speeds in multiple-cylinder engines.

4. By the use of auxiliary exhaust ports, combined with surface radiation.

5. By forced draught of air circulating through an air jacket around the cylinder.

The greater majority of air-cooled engines have rotary fans attached, for the purpose of increasing radiation with air currents at high speed.

**The Theory of Cylinder Cooling.**—The prime necessity involved in efficient means for cooling a gas-engine cylinder is that the temperature of the cylinder is normally maintained below the point at which the lubricating oil will otherwise carbonize. Furthermore, the walls would also become so heated that the fuel charge would be fired out of time, with the result of disarranging the cycle and stopping the engine. Although the "cooling system" is a positive necessity over the combustion space, for the reasons above stated, it forms a serious consideration in estimates on efficiency by absorbing a large proportion of the heat units generated by ignition of the fuel, and thus, under any conditions operating to reduce the total theoretical efficiency, even though by a very small fraction.

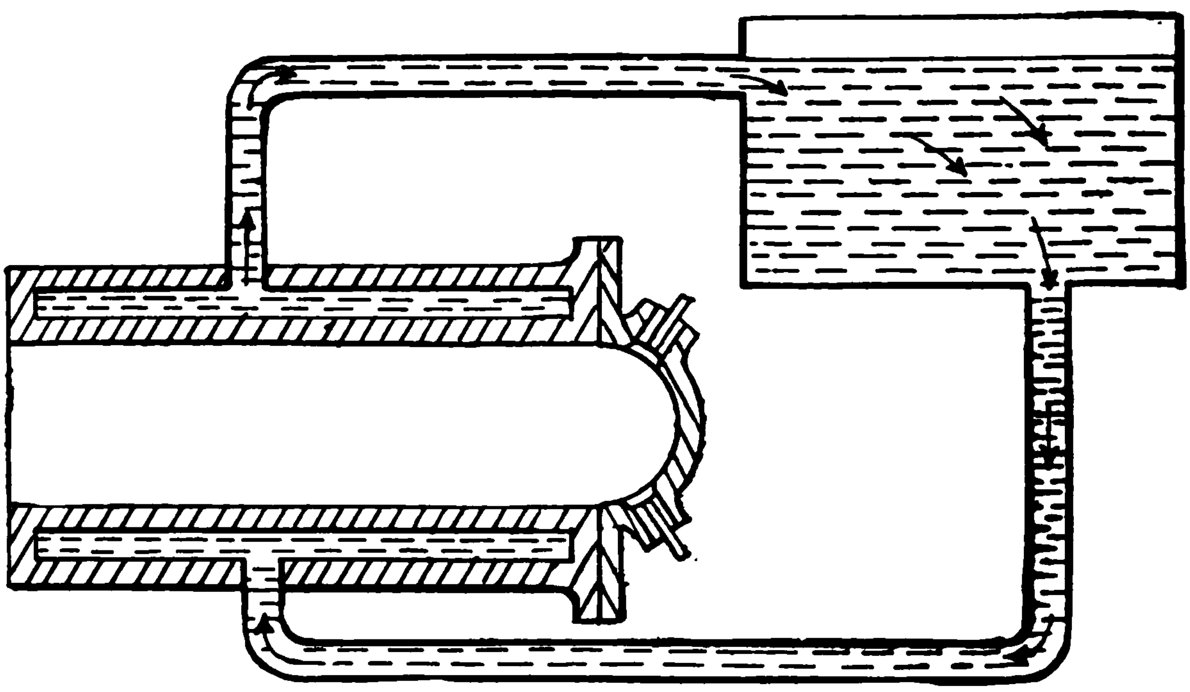


FIG. 139.—Diagram of a Gravity Water-Circulation System for a Gas-Engine Cylinder. As indicated by the arrows, the water from the tank enters the jacket of the cylinder at the lowest point, and being there subjected to the heat of the cylinder walls, rises to the level of the tank water; thus maintaining a continuous circulation.

**Jacket Water: Its Rate and Quantity.**—On this point Hiscox makes an interesting statement on the proportions of absorbed and efficient heat units, as estimated under typical conditions. He says:

"In regard to the actual consumption of water per horse-power and the amount of heat carried off by it, the study of English trials of an Atkinson, a Crossley, and a Griffin engine showed 62 pounds of water per indicated horse-power per hour, with a rise in temperature of 50° F., or 3,100 heat units carried off in the water out of 12,027 theoretical heat units that were fed to the motor through the 19 cubic feet of gas at 633 heat units per cubic foot per hour.

"Theoretically, 2,564 heat units per hour are equal to one horse-power. Then, 0.257 of the total was given to the jacket water, 0.213 to the indicated power, and the balance, 53 per cent., went to the exhaust, radiation and the reheating of the previous charge in the clearance and in expanding the nitrogen of the air. * * *

"In a trial with a Crossley engine, 42 pounds of water per horse-power per hour were passed through the cylinder jacket, with a rise in temperature of 128° F.—equal to 5,376 heat units to the water from 12,833 heat units fed to the engine through 20.5 cubic feet of gas at 626 heat units per cubic foot."

**Gas Consumption and Power Efficiency.**—On the point of gas consumption per horse-power under varying conditions, Hiscox states:

"An experimental test of the performance of a gas engine below its maximum load has shown a large increase in the consumption of gas per actual horse-power, with a decrease of load, as the following figures from observed trials show: An actual 12 H. P. engine at full load used 15 cubic feet of gas per horse-power per hour; at 10 H. P., 15½ cubic feet; at 8 H. P., 16½ cubic feet; at 6 H. P., 18 cubic feet; at 4 H. P., 21 cubic feet; at 2 H. P., 30 cubic feet of gas per actual horse-power per hour. This indicates an economy gained in gauging the size of a gas engine to the actual power required, in consideration of the fact that the engine friction and gas consumption for ignition are constants for all or any power actually given out by the engine."

**Efficiency and Structural Conditions.**—As already stated, an increase in compression, involving a smaller combustion chamber or a longer stroke, ensures a higher temperature and explosive force at ignition. But, in obtaining these ends by a relatively longer piston-sweep, we are met by the difficulty of exposing the ignited gas to a commensurately larger area of heat-absorption through the circulating jacket-water. It is obvious, therefore, that economy in this respect must be obtained by some mechanical or physical variation in the conditions of operation.

**Heat Economy: High Speeds.**—For example, considerable economy in fuel-consumption may be obtained by increasing the speed of the engine, which, when the cycle is well established, involves that the explosive impulses succeed one another so rapidly

that the percentage of heat units absorbed by the jacket water is constantly reduced. Such a reduction of power-output involves, of course, a lower speed, and is accomplished by regulating the gas and air supply. But if, according to the figures quoted above, a 12 H. P. engine at full power consumes 15 cubic feet of gas per horse-power per hour, which is 180 cubic feet per hour, it will at 10 horse-power consume 155 cubic feet, or 86 per cent.; at 8 horse-power, 132 cubic feet, or 75 per cent.; at 6 horse-power, 108 cubic feet, or 60 per cent.; at 4 horse-power, 84 cubic feet, or 46 per cent., and at 2 horse-power, 60 cubic feet, or 33 per cent. The waste in fuel gas under low speed and low power conditions may thus be readily understood—one-sixth of the stated horse-power from one-third of the full gas supply.

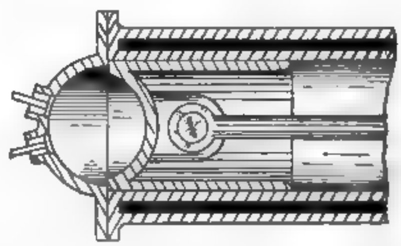


FIG. 140.—Section through a Gas Engine Cylinder having a spherical clearance and a spherical depression on the piston head. The shaded sections at top and bottom indicate the water jackets. The concavities are somewhat greater than are met in general practice. Few builders use the concaved cylinder head.

**Heat Economy: Spherical Clearance.**—A number of gas engines achieve an economy in the use of heat and power units by having the piston and the combustion chamber of concave profile, so as to form a spherical, spheroidal or elliptical clearance at the end of the in-stroke. That is to say, the rear end of the cylinder is dome-shaped and unjacketed, and the opposing end of the trunk piston is correspondingly hollowed or concaved, thus providing a large uncooled surface at either end of the combustion chamber during the entire cycle. Indeed, while this arrangement permits of a clearance at the end of the in-stroke, of the smallest possible area on the cylinder walls, it provides a total increase in clearance volume on a stated wall surface between 20 and 40 per cent. in engines of ordinary design.

Hiscox estimates that, while the wall surface of a cylindrical clearance space of one-half its unit diameter in length contains 3.1416 square units and 0.3927 cubic unit, the same surface in square unit measure, with a spherical combustion chamber has a volume of 0.5236 cubic unit, representing a gain in volume of 33⅓ per cent. (5236—3927=1309×3=3927). Such superior volume, on equal wall surface, being fully available at the moment of explosion, when the greatest possible degree of heat and pressure is desirable to promote expansion, must vastly increase the effective power of the engine.

**Heat Economy: Temperature of Water.**—Another consideration of importance in calculating for heat economy in a gas engine is that the temperature of the jacket water should be maintained at a point favorable to moderate absorption of superfluous heat. The temperature of the water must not be too low—the cooling must not be a *freezing* process; since, as is evident from foregoing statements, the efficiency of the engine will fall accordingly. The best practice is to supply water to the jacket at a temperature of a few degrees below the boiling point, permitting it to be returned to the reservoir at a temperature slightly above.

**Heat Economy: Rate of Absorption.**—A prominent American gas engine authority writes:

"A motor is hotter when the water is boiling rapidly than when it is boiling slowly, and the fact that more heat units are being absorbed by the water proves that the engine is doing harder work and not that it is cooler than before. The writer favors boiling water as the proper temperature and a gravity circulation as the proper circulating method, because this method most nearly insures a fixed temperature for the motor to work under. If kept below the boiling point the temperature of the motor will vary as the work varies. If air-cooled it will vary with the wind or the speed of the vehicle. If circulated by the pump the temperature will vary as the speed of the pump varies, but with the boiling water system it remains reasonably constant and permits the finest adjustment of the mixture and the best results from the sparking."

**Heat Economy: Rate of Water Circulation.**—The plea for gravity, or thermo-siphonic circulation, just quoted, does not represent the opinions of many experts. Thus, an able writer on gas engines in a leading periodical says:

"The more rapidly the water passes through the jacket, the lower will be the temperature of the issuing jacket water, but the heat units will be greater, within the usual limits of practice. For example, suppose the jacket water passes through at the rate of 16 pounds a minute and rises from 60° F. to 140° F. in passing through. To raise 16 pounds of water 80 degrees requires 1,280 B T. U. (British thermal units), and as the

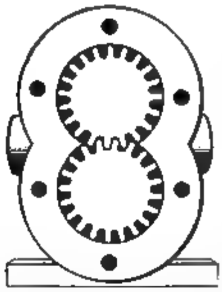


FIG. 141.

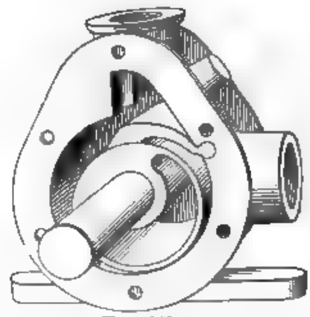


FIG. 142.

FIGS. 141-142.—Two Types of Circulating Pump for Use in the Water-Cooling System of Gas Engines. In both cases the water is raised by the use of a rotating water-tight piston, being compelled to follow the designed course by the reduction of the space it can occupy around the shaft of the piston.

difference between the average temperature within the cylinder (usually about 1,000° F.) and that of the jacket water (in this case 100°) is 900 degrees, there are 1,422 heat units per minute transmitted through the walls of the cylinder per degree of difference between inner and outer average temperatures

"Now reduce the rate of flow of the jacket water to 9.57 pounds, and, assuming that the average temperature in the cylinder remains constant, the water will issue at a temperature of 190° F. This means a rise of 130 degrees, and to heat 9.57 pounds of water per minute 130 degrees, will require $9.57 \times 130 = 1{,}244$ heat units per minute, which is 36 less than before. A saving of 36 heat units per minute means

$$\frac{36 \times 778}{33{,}000} = .8487 \text{ H. P., gross.}$$

"As a matter of fact the flow of water would need to be less than 9½ pounds a minute in order to raise the temperture to 190° F., because as the jacket water increases in temperature, the average temperature in the

cylinder increases, making the difference between the two less than if the internal temperature remained constant. This decreases the transmission of heat units to the water. The effect of varying the flow of jacket water cannot be computed accurately, because the internal temperature cannot be computed, and the exact heat conductivity of the cylinder walls is unknown. But, as the foregoing rough example clearly shows, the temperature of the issuing jacket water should be kept as high as practicable by adjusting the rate of flow.

"The limit to the allowable increase in jacket water temperature is set by the cylinder oil. The cylinder walls must not be allowed to become so hot as to decompose the oil, for the very obvious reason that decomposed

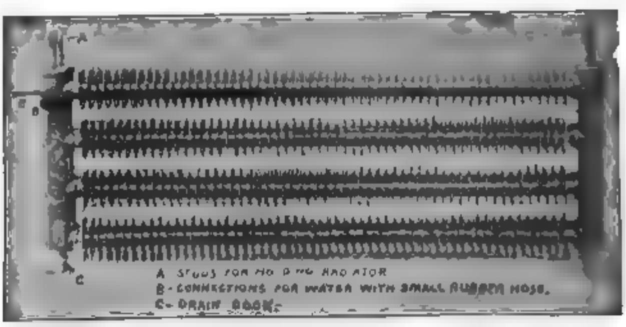



FIG. 143.—Fin Cooled Radiating Tubes for Use on Light Gasoline Carriages, with parts and connections indicated.

oil does not lubricate. When the construction of an engine is such that the piston cannot be inspected there is no reliable way of determining the conditions of lubrication at high temperatures without endangering the cylinder wall and piston surface But, as a rule, the jacket water can be run up to 200° F. without risk of decomposing the cylinder oil, if a first-class oil is used."

**Heat Economy: Regulating Jacket-Water Temperature.**— If we play a hose upon the surface of a gas-engine cylinder, the absorption of heat will be so rapid that motion will cease. Conversely, the efficiency of the engine, within limits, increases with the rise in jacket-water temperature. The limits under ordinary conditions of operation are set at the point when the water begins steaming. It is necessary, therefore, to provide for the radiation of enough thermal units to keep the water from changing its form. For this purpose radiators of the several forms known to automobile construction are used.

**Radiators for Cooling Jacket Water.**—After leaving the water jacket of the engine, the water is forced through the radiator, before being returned to the tank. Radiators are made in two general styles:

1. Radiators composed of coils of tubing having a number of metal gills or fins let over the tube circumference.

2. Radiators consisting of a flat tank pierced with a multitude of small tubes—like the flues of a boiler. This kind is the well-known Mercedes cellular or "honeycomb" radiator.

Both varieties of radiator are made preferably of copper, a metal having a high heat-conducting capacity.

In both varieties of radiator the water is cooled by air currents passing through the fins or flue-tubes, extracting the heat, in proportion to the available cooling surface exposed.

**The Dimensions of Radiators.**— The following data are given for the dimensions of radiators of both varieties :

The cooling surface of a *tubular radiator,* stated in square inches, is the product of the length of the tubes by their circumference, plus the area of one fin multiplied by the total number of fins.

The cooling surface of a *cellular radiator,* stated in square inches, is the product of the circumference of one cell or flue multiplied by its length, multiplied by the number of cells or flues.

The usually accepted standard for radiator dimensions requires 5 square feet of cooling surface per indicated horse-power. This gives 9 feet of ⅝-inch tube, or 6 feet of ¾-inch tube per indicated horse-power.

## CHAPTER TWENTY-TWO.

### AIR-COOLING FOR THE CYLINDER.

**Air Cooling for Cylinders.**—While, as a general proposition, it may be said that the cooling of a gas-engine cylinder is best accomplished by water-circulation, a number of recent carriages both light and heavy have successfully used air-cooling devices. To within a very few years it has been held that air cooling is impracticable for vehicle motors, and, on the basis of trials made by French builders, the statement has always been made that, while an air-cooled cylinder will work very well on a light high speed vehicle or cycle, it is impossible for automobiles of large

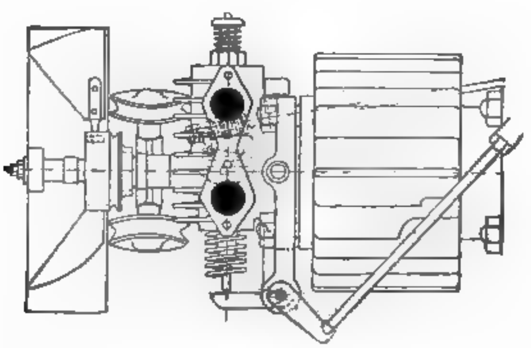


FIG. 144.—Detail Cylinder Head of the Simms Cycle Engine, showing fan wheel, cooling ribs, and peculiar arrangement for opening the exhaust.

power, particularly in climbing hills and in hot weather. Daimler's early motors were air cooled by means of a rotary fan on the crankshaft that created a forced draught through an air jacket surrounding the cylinder, as is shown in a subsequent cut. Later on, automobile builders, such as Mors, Decauville, Darracq, and also Panhard-Levassor, used motors on heavy carriages with the cylinders cooled by peripheral fins or flanges. The principal trouble with these cylinders was that under heavy load the generating of heat was so rapid as to clog the piston, ignite the

lubricating oil, or to produce premature explosion of the charge. Largely for this reason, the water-cooling system became universal, except for very light vehicles and cycles intended to be driven at high speeds. In order to assist the work of cooling the cylinder, several builders early adopted the plan of using rotary fans to create a forced draught against the fins cast on the cylinder's walls. Such a device greatly increased the cooling properties of the motor, even when the vehicle was moving at low speed. This was particularly true with the Simms fan-cooled cylinder, on the

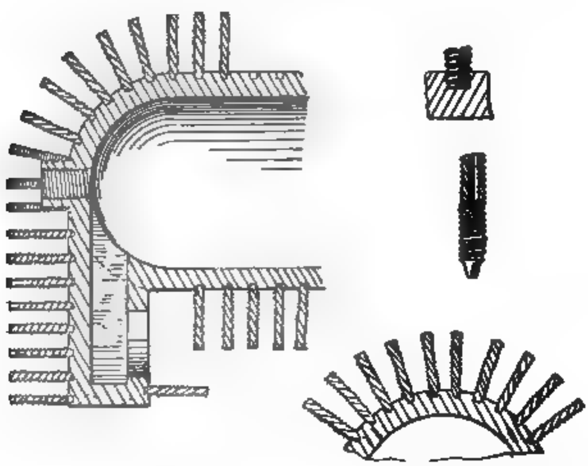


FIG. 146.—The Knox Pin-Cooled Cylinder. In this engine, pins are used for radiating instead of the usual flanges or ribs as on other air-cooled cylinders.

walls of which were cast very deep longitudinal flanges. An English builder, Turell, constructed a three-wheeled carriage propelled by a motor with ribs of this description. It was found however that, with a motor of 2 horse-power, and over, the draught created at high speed was not sufficient for cooling and that the cylinder would quickly become overheated, with the result the exhaust walls would be loosened and the head frequently red hot. It seems to have been reserved for American inventors to design successfully air-cooling systems. One of the most noteworthy of this is the Knox pin-cooled cylinder, in which a

large number of brass pins are screwed into suitable holes on the outside of the cylinder's wall. According to claims this device increases the cooling surface nearly 100 per cent., and is exceedingly efficient in utilizing the heat absorbing properties of air under draft. In connection with the use of corrugated pins on the outside surface of the cylinder, a rotary fan is used, and

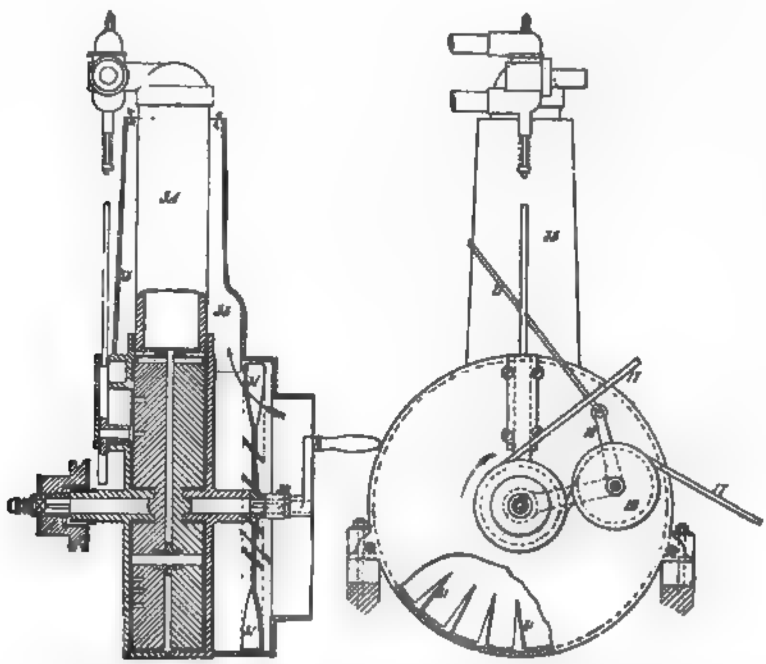


FIG. 146.—Diagram of the earliest Daimler Gasoline Engine, showing method of cooling the cylinder by air forced through an air jacket surrounding it. The parts are indicated by number as follows: 17 is the driving belt passing around the pulley on the main shaft and tightened by jockey pulley, 9, and link, 21. 31 is a rotary fan, consisting of a number of radial fins as shown, which keeps a current of air passing through the air jacket, 33. 34 is the cylinder shown in part section.

this, being driven direct from the main shaft by a worm gear, always rotates with the speed of the engine, thus providing a sufficient draught for cooling purposes at all speeds. The problem has been differently solved by other American inventors. Thus the builders of the Crest carriage use a cylinder with deep longitudinal flanges, which according to claims and re-

ported tests is very efficient in spite of the fact that the motor is set vertically in the carriage. Briefly described, the flanges are so arranged as to be deepest over the combustion spaces, thus giving the cylinder an approximate pear shape. The success of the air cooling is due to the extremely large radiating surface, due to the use of very wide vertical radiating vanes, to the free passage of air directly behind the valve chamber—this space being

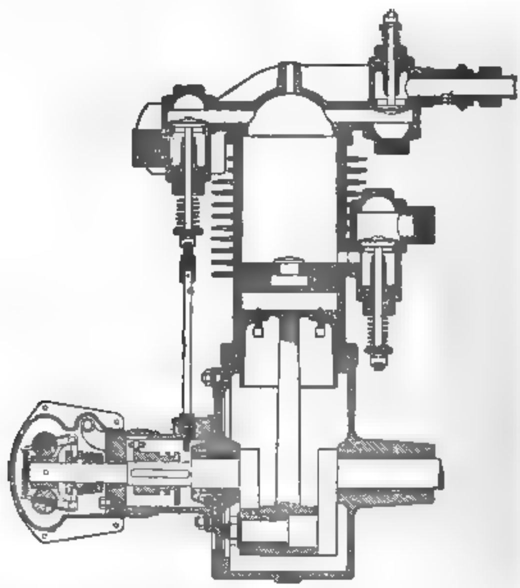


FIG 147.—Section through the Fritscher-Houdry Single-cylinder Engine, showing the supplementary or "anticipatory" exhaust valve at the point of piston outstroke. The supplementary exhaust used on modern engines is similar to this, only mechanically operated.

usually filled with solid metal—and to the slight tapering of the upper end of the piston. The motor is of the conventional vertical type, excepting that the inlet and exhaust valves are larger in proportion to bore than is usually used. According to claims, apparently verified by independent test, it can safely run at a speed of between 1,900 and 2,000 revolutions per minute.

For air-cooling the cylinders of the Regas engine, a sheet steel jacket carrying numerous copper tubes, each having a longitud-

inal slot at its base, is slid over the walls. As heat is generated in the operation of the engine, a circulation of air is set up, the hot air being given out at the ends of the tubes, on the principle of the Bunsen burner. In this manner, there is a constant supply of cool air for absorbing the heat of the cylinder and the circulation is maintained without a fan or other mechanical contrivance.

The Franklin system of air cooling is different from any of the fore going devices, and, judging from its numerous imitators,

FIG. 148.—Cylinder of the Regas Engine, showing Bunsen tubes let into steel jacket.

embodies the correct principle for cooling a medium to heavy weight gasoline engine. Briefly described, it consists in using a multiple cylinder engine; in the first models four cylinders, and latterly six. The primary effect of using four cylinders is that any desired degree of power may be achieved with shorter strokes and smaller pistons than would be possible with either one or two cylinders. The area of the combustion space being reduced, the heat may be more quickly radiated from the engine. Franklin also uses a supplementary exhaust situated at or near the point

of piston out-stroke, so as to be uncovered precisely like the exhaust port in a two-cycle engine. The supplementary exhaust greatly facilitates the expulsion of the burnt out products of combustion. The port opens into a small chamber, normally closed by a poppet valve, which is opened at the proper moment, thus giving an exhaust from both top and bottom of the cylinder. A very similar arrangement was adopted by Fritscher and Houdry as early as 1900, but proved only indifferently effected on a single-cylinder engine.

Other engines, notably the Marion, achieve the end of efficient air cooling by using an exhaust valve of unusually large area. Frayer and Miller enclose the cylinders of their engine with an air jacket through which air is forced by a blower, on a principle precisely similar to water circulation forced by a rotary pump.

Briefly expressed the requirements for effective air cooling are:

1. Radiating surface, large in proportion to the outside area of the cylinder.

2. Large exhaust valves, or some mechanical means for increasing the speed of the exhaust.

3. Combined with these two, a multiple cylinder engine.

# CHAPTER TWENTY-THREE.

## POWER ELEMENTS OF A GAS ENGINE.

**Power Efficiency and Fuel Consumption.**—As we have already learned, there are various conditions, both physical and mechanical, that prevent the realization of the full theoretical effect of the heat actually expended in a gas-engine cylinder. Ideally speaking, the efficiency of such an engine should be expressed by this formula:

$$\frac{\text{Temperature rise in degrees}}{\text{Explosion Temperature}} = \frac{T''-T'}{T''}$$

Substituting the average figures previously found, we have this expression:

$$\frac{3000-660}{3000} = \frac{2340}{3000} = .78.$$

This would involve that about 78 per cent., on the average, was the actual *heat efficiency* of a good gas engine. The results, however, are far below this; for, even allowing for all the apparently unavoidable losses in the process of transforming heat into actual work, we find that the real average makes the *actual mechanical efficiency,* in terms of *brake horse-power,* about 80 per cent. of the calculated efficiency, in terms of *indicated horse-power.* Thus:

$$\frac{\text{B. H. P.}}{\text{I. H. P.}} = \frac{8}{10} = .80.$$

This is generally about 17 per cent. of the total heat expended, and seldom more than 20 per cent.

**Mechanical Equivalent of Heat.**—Now, one horse-power is 33,000 foot-pounds per minute, and 778 foot-pounds equals one thermal unit, which equation expresses the *mechanical equivalent of heat.* Whence, one horse-power per minute equals 42.42 thermal units, which is, by the hour, 2,545.2 thermal units. Then 10 H P. equals 25,452 thermal units and 8 H. P. equals 20,361.60 thermal units. Whence we have:

$$\frac{20361.6}{25452} = .80.$$

If, however, 10 H. P., or 25,452 B. T. U. per hour be assumed equivalent to the I. H. P. of a given engine, which is, as a general average, 26 per cent. of the total heat equivalent supplied to the engine in the shape of fuel, we have it that the total theoretical value of the fuel should be 97,892.31 B. T. U., or 38.46 H. P.

According to one authority, the average heat expenditures found in a number of tests of gas engines is as follows:

| | |
|---|---|
| To the jacket water.............................. | 52 per cent. |
| To loss in the exhaust........................... | 16 " " |
| To loss in radiator, etc......................... | 15 " " |
| To useful work (B. H. P.)...................... | 17 " " |

This shows a total of 83 per cent. lost for any efficient mechanical work realized, or useful, at best, only for maintaining necessary interior conditions. Accepting these figures as fairly typical, we find for 10 I. H. P., or 26 per cent., a total of 97,892.31 thermal units, or the heat equivalent of 38.46 H. P. by the hour theoretically, fed to the cylinder in fuel mixture.

Then reducing the above table to terms of heat equivalence, we have:

| | | | | |
|---|---|---|---|---|
| 52% | = | 50904.00 B. T. U. | = | 20.000 H. P. |
| 16% | = | 15662.77 B. T. U. | = | 6.154 H. P. |
| 17% | = | 16641.69 B. T. U. | = | 6.538 H. P. |
| 15% | = | 14683.85 B. T. U. | = | 5.765 H. P. |
| 100% | = | 97892.31 B. T. U. | = | 38.457 H. P. |

**Experimental Figures.**—Another authority, as quoted by several writers, finds the following results from a series of experiments with a 125 H. P. gas engine: At full load 26 per cent. of the heat energy is converted into mechanical energy, 44 per cent. is lost through the exhaust and by radiation, and 30 per cent. is absorbed by the jacket water, or a total loss of 74 per cent. At three-quarter load, the figures become 25, 38 and 37 per cent., respectively, a total loss of 75 per cent; at one-quarter load, 18, 28,

54, a total loss of 82 per cent.; and, when running free, 10, 32 and 58 per cent., a total loss of 90 per cent. These figures show that the percentage of loss through the exhaust increases as the jacket loss decreases. Other recorded tests show similar figures.

**Calorific Values of Fuels.**—As we have already learned, some causes of lost efficiency lie in the mechanical constructions at present necessary in gas engines; others, in the inevitable waste due to the operation of physical laws and forces; others, again, in improper mixtures and defective ignition apparatus. Other things equal, however, the kind of fuel used is the most important consideration in securing a high power per pound of fuel. This is particularly emphasized in the fact that the various substances suitable for use as fuels in gas engine cylinders differ greatly in calorific values.

As given by reliable authorities, the calorific values of several common hydrocarbon fuels, as expressed in British thermal units, are as follows:

| | Per Pound. | Per Cubic Foot. |
|---|---|---|
| Marsh gas ($C\,H^4$) | 23,594 | 1,051 |
| Benzine ($C^6\,H^6$) | 18,448 | —— |
| Gasoline | 21,900 | 690 |
| Acetylene ($C^2\,H^2$) | 21,492 | 868 |
| Ethylene ($C^2\,H^4$) | 21,430 | 1,677 |
| Natural gas | —— | 900 to 1,000 |
| Illuminating coal gas | —— | 600 to 800 |
| Water gas (average) | —— | 710 |

**Determining Calorific Values.**—Knowing the specific heat of a given gas at constant volume, the calorific value in thermal units may be discovered as follows, in order to estimate the thermal efficiency of an engine:

$$H = C\,(T'' - T').$$

In this formula H is the calorific value in thermal units; C, the specific heat at constant volume; T″, the temperature of explosion, and T′, the initial temperature. The specific heat for a 9 to 1 mixture of air and coal gas being 0.1846; a typical explosion temperature 2,764 degrees, absolute, and an average compression tem-

perature, 921 degrees, we have 340.21 thermal units per pound of the initial charge.

**Determining the Explosion Pressure.**—The maximum or explosion pressure of a gas engine is equal to the ratio between the compression and maximum temperatures multiplied by the compression pressure. Thus:

$$\frac{Ct}{Et} \times Cp = Ep.$$

Substituting the values given above for a given engine, we have:

$$\left(\frac{2764}{921} = 3\right) \times 68.86 = 206.58 \text{ pounds,}$$

which, as may be seen, is the same as was given in a former chapter:

$$P'' = \frac{T''\ P'}{T'}.$$

**Horse-Power in Terms of Heat Units.**—In order to estimate the mechanical efficiency of a given engine we must, as shown above, know the *delivered horse-power.* While there are numerous ways of calculating this, the simplest and readiest formula for a one-cylinder engine is as follows:

$$\frac{D^2\,L\,R}{18{,}000} = \text{D. H. P.}$$

This means that the square of the *piston diameter, D,* in inches is to be multiplied by the *length* of the stroke, *L,* in inches and the number of *revolutions* per minute, *R,* of the fly-wheel, and the product divided by 18,000.

The denominator 18,000 is given by Roberts as the proper figure for a four-cycle gasoline engine. For four-cycle engines using coal gas, the denominator would be 19,000. For two-cycle engines using gasoline, the denominator would be 13,500; for other types, 14,000.

**The Delivered Horse-Power.**—To apply this formula we will take a highly efficient three-cylinder gasoline vehicle motor with

proportions as follows: The piston diameter is 4.5 inches; the stroke is 4.5 inches; the number of revolutions per minute is 900. Then, substituting, we have:

$$\frac{20.25 \times 4.5 \times 900}{18{,}000} = \frac{82{,}012.5}{18{,}000} = 4.56 \text{ H. P.}$$

In calculating for more than one cylinder, we have the formula:

$$\frac{D^2 \, L \, R \, N}{18{,}000} = \text{H. P.}$$

in which N is the number of cylinders. Hence, for three cylinders:

$$\frac{82{,}012.5 \times 3}{18{,}000} = 13.67 \text{ H. P.}$$

According to the claims of the manufacturer, the engine in question yields no less than 12 D. H. P. by actual brake tests.

**The Time Element in Power Estimates.**—In the determination of horse-power the *time* element is an important item, because the power to be calculated produces motion, and is not a static pressure to be measured only in terms of pounds weight. It is important also to remember that the power efficiency increases with the rate of motion, being expressed in terms of revolutions per minute of the fly-wheel or crank shaft. Thus, a given engine running with low gas supply or high load may rotate the fly-wheel only 200 times per minute, while, with full gas supply, or at average load, it can produce as many as 2,000 revolutions per minute. Furthermore, the available power decreases as does the number of revolutions per minute, while, as has already been indicated, the rate of gas consumption per unit of work is increased. Thus it is important to know, in making estimates for horse-power whether the engine in question is running free or under load.

**Engine Dimensions in Power Estimate.**—Next to this, the most important consideration refers to the dimensions of the piston and cylinder and the length of the stroke. For, since these figures indicate the power capacity of the engine, in point

of the quantity of fuel consumed, and the power developed by explosion, as acting on the reciprocating parts, they, together with the ascertained rate of motion, are in ratio to a figure equivalent to an average ratio between the operative dimensions of the cylinder—these are given above in Roberts' formula for D. H. P. —and the delivered horse-power. The formula is further verified in the fact that the piston diameter and length of stroke are in discoverable proportion to the D. H. P. and the number of revolutions of the fly-wheel. So that an engine giving, say, 35 D. H. P. at 600 revolutions per minute, with a fuel whose thermic value is known, must have a certain diameter of piston and length of stroke. These facts will be evident from examination of specimen formulæ.

**The Indicated Horse-Power.**—In making more definite calculations on the power of a gas-engine there are four points to be considered:

1. How great is the mean effective pressure per square inch on the piston during the power stroke?
2. What is the area of the piston?
3. What is the length of the stroke?
4. What is the number of explosions per minute?

The ratio between the product of these factors and 33,000 gives the I. H. P. per minute. Thus:

$$\frac{\text{Pressure} \times \text{area} \times \text{stroke} \times \text{E. P. M.}}{33{,}000} = \text{I. H. P.}$$

To reduce this ratio to a practical formula we take the product of the mean effective pressure of the power stroke; by the area of the piston *in square inches;* by the length of the stroke in feet; by the number of explosions per minute, and divide by 33,000, which figure expresses the number of foot-pounds per minute per horse-power. Thus:

$$\frac{P\,A\,S\,E}{33{,}000} = \text{I. H. P.}$$

**The Mean Effective Pressure.**—As may be understood from the term itself, the mean effective pressure is an average for the

pressure in pounds per square inch brought to bear upon the piston of a cylinder during the power stroke. It has been well defined as "the difference between the average gauge pressure shown by the expansion line and that shown by the compression line, minus the back pressure of charging or suction." As all these operations are depicted on the indicator diagram an average of its proportions will yield the desired result.

**The Brake Horse-Power.**—The most satisfactory method of testing the effective power of an engine is by the use of Prony's brake, one form of which is shown herewith. Briefly, it consists

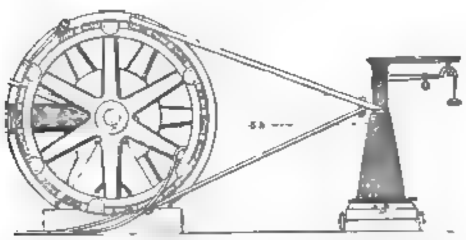


FIG. 150. Common Form of Prony Brake, for testing the D. H. P. of an engine. An iron band shod with wooden blocks is drawn tightly around the circumference of the fly-wheel To this two arms are attached, the other ends of which bear upon the scale platform, as shown. It is necessary that the scale platform be raised to the same height as the centre of the fly wheel shaft. The length of leverage is indicated as 5 feet 3 inches, the diameter of the wheel being 8 feet. These two factors, the R P M. and the recorded weight, are the essential elements in the determination of power as by the above formula.

of a band of rope or strip iron—the latter is the arrangement shown—to which are fastened a number of wooden blocks, several carrying shoulders to prevent the contrivance from slipping off the wheel rim. Being applied to the circumference of the fly-wheel the brake band is drawn tight, as shown, so that the blocks press against the surface all around. The brake, thus formed, is prevented from revolving with the fly-wheel, by two arms, attached near the top and bottom centres of the wheel, and joined at the opposite ends to form a lever, which bears upon an ordinary platform scale, a suitable leg or block being arranged to keep its end opposite to the centre of the shaft. By this arrangement the amount of friction between the brake band and the revolving wheel is weighed upon the scales. For, since the brake fits

tightly enough to be carried around by the wheel, but for the arms bearing upon the scale, the amount of frictional power exerted by the wheel in turning free within the blocks may be transmitted and measured, just as would be the case were a machinery load attached, instead of a friction brake.

**Formula for Brake Horse-Power.**—Accordingly, the factors in estimating the actual power developed are:

1. The circumference of the wheel.
2. The length of the leverage, measured on the line drawn from the centre of the rotating shaft to the centre of the scale platform.
3. The number of revolutions per minute.
4. The weight in pounds registered by the scale, less the static weight of the brake lever arms and block resting on the platform.

With this form of Prony brake the formula for delivered horse-power is as follows:

$$\frac{W \times N \times L \times C}{33{,}000} = \text{B. H. P.}$$

In this formula W is the net weight of the wheel effort, as shown by the scale; N, the number of revolutions per minute; L, the length of the leverage; C, the circumference of the braked fly-wheel. Their product gives the number of foot-pounds developed; the quotient of the indicated division by 33,000 gives the actually efficient horse-power.

If, therefore, a given engine has a fly-wheel of 16 inches diameter, revolving at 600 revolutions per minute, and giving 27.5 pounds at the scale, with a leverage of 5 feet, we have, according to the above formula:

$$\frac{27.5 \times 600 \times 5 \times \frac{3.14159 \times 16}{12}}{33{,}000} = \frac{345{,}574.35}{33{,}000} = 10.47 \text{ B. H. P.}$$

The diameter, 16 inches, being multiplied by 3.14159, the expression for the ratio between the circumference and diameter of a circle, gives 50.2655 inches, which, divided by 12, gives 4.189 feet approximately.

**Other Forms of Prony Brake.**—In some forms of Prony brake the block-bearing rope or band, instead of being secured as shown in the cut is attached to the floor and ceiling—two dynamometers or spring balances being interposed. Thus in the formula for estimating with this form, the item of leverage length is omitted, the expression being:

$$\frac{W \times N \times C}{33,000} = \text{B. H. P.}$$

As may be readily understood the scale weight in this case would equal the product of the weight and leverage length with the other formula.

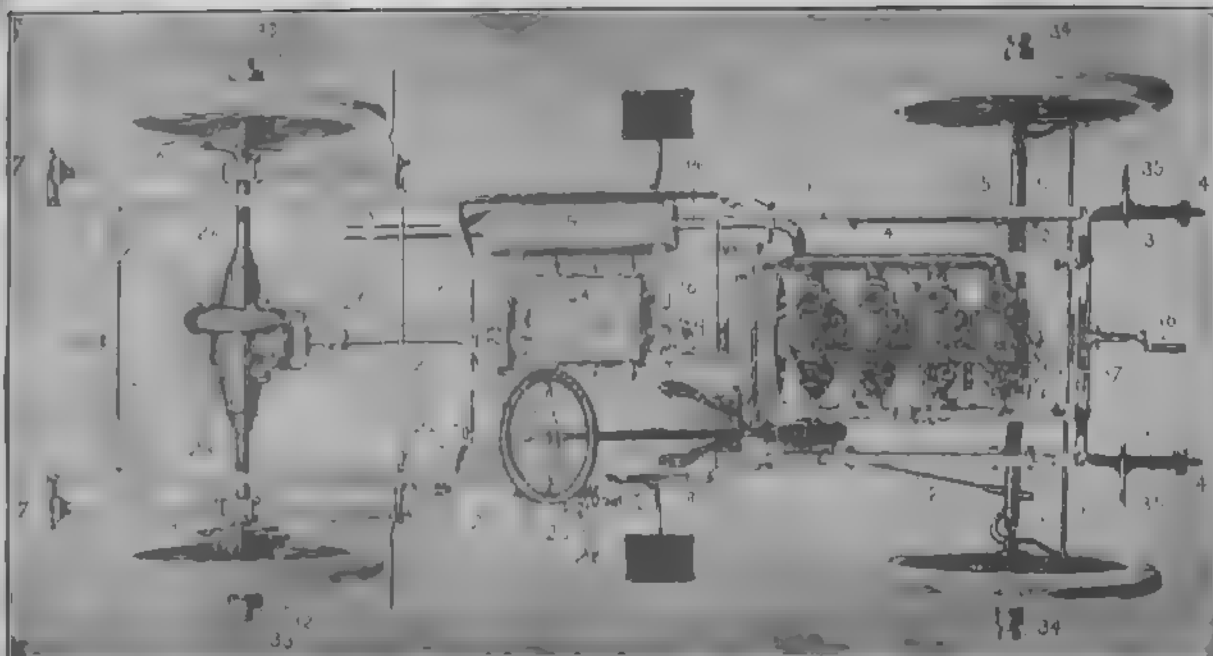


PLATE II. Chassis of an American Four-cylinder Car, showing parts numbered: steel frame (1); motor and transmission frame (2), front springs (3), spring toggles (4), spring clips (5), rear springs (6); spring toggles (7); spring clips (8); front axle tubes (9), steering knuckles (10); steering link (11), steering rod (12), steering wheel (13), exhaust pipe (14), muffler (15), starting crank (16), clutch pedal (17); brake pedal (18), gear shifting lever (19); brake lever (20); battery box hangers (21); interlocking device for gear shift, brake and clutch (22), foot brake band (23); transmission gear case (24), driving shaft (25), distance-rod (26); differential case (27), rear axle tubes (28), brake drums (29), brake bands (30), hub clutch bands (31), hub clutch plates (32), hub caps (33), front hub caps (34), lamp brackets (35); coupling on clutch shaft (36); cover for second-motion gears on motor (37)

# CHAPTER TWENTY-FOUR.

## CARBURETTERS AND CARBURETTING.

**The Carburetter and its Function.**—In motor carriage parlance any apparatus for vaporizing a liquid hydrocarbon, and mingling it with air in proper proportions, is known as a carburetter. Some authorities contend that the word applies properly to one particular type—the ebullition carburetter—and that all others are merely vaporizers. To the average mind this is probably very much like a "distinction without a difference," since "carburetters" and "vaporizers" accomplish the same result in the end; also, the usage seems so firmly established that nothing is to be gained by opposing it. We will, therefore, apply the word "carburetter" to all forms of vaporizing apparatus used in connection with a gasoline engine.

**Varieties of Carburetter.**—Classified according to structure and operation, there are three varieties of carburetting apparatus:

1. *The surface carburetter,* operating to produce a fuel mixture when air is passed over the surface of a body of liquid hydrocarbon, or circulates around a gauze, wicking or metal surface saturated with such a liquid.

2. *The ebullition or filtering carburetter,* in which air is forced, under suction, through a body of liquid, from bottom to top, so as to absorb particles of its substance.

3. *The float-feed carburetter or sprayer,* in which the liquid hydrocarbon is sprayed or atomized, through a minute nozzle and mixed with a passing column of air.

Of these types, only the *first* and *third* have been widely used with motor carriage engines. The sprayer is now the prevailing form.

**Carburetter Operation.**—According to operation, we may distinguish two varieties of carburetter:

1. *The permanent adjustment carburetter,* used with engines controlled by valve governors.

2. *The variable adjustment, or throttling carburetter,* used with engines controlled by throttle governors.

The throttling carburetter may be said to have two varieties:

1. *The mixture throttler,* in which the proportion of air is varied, according to requirements, by regulating the opening of the air supply valve, thus varying the power effect of explosion.

2. *The volume throttler,* in which the proportions of air and gas are predetermined by permanent adjustment, but the volume is regulated by the opening of the fuel supply valve to the cylinder.

In this classification, again, we have a distinction depending very largely upon the form of engine governing in use. Many authorities prefer governing by varying fuel volume, but the practice of governing by varying the mixture at fixed volume seems to be prevalent.

**Early Forms of Carburetter.**—Among early forms of carburetter, we find both the surface and filtering types. Benz used a complicated surface instrument on his early vehicle motors, but Daimler began with a filtering carburetter, which he subsequently abandoned for the Maybach float-feed sprayer, the prototype of all subsequent instruments of its class.

**Daimler's Filtering Carburetter.**—Daimler's filtering carburetter consisted of an elongated cylindrical vessel, which was partially filled with gasoline. Upon this liquid was a hollow cylindrical float, the shell of which was slightly depressed upon the upper face, so that the gasoline rising through the hollow in the centre could be readily exposed to the action of the air, drawn through the vessel by the suction of the piston. The float also carried a vertical tube, which reached upward through the top of the inclosed cylindrical vessel, sliding freely in a second tube of larger diameter, in order that the float might rise or fall to the

level of the gasoline. In the top was also set a cylinder of smaller diameter, having a rotary valve in its top for admitting air, and having its base connected with the interior of the main cylindrical

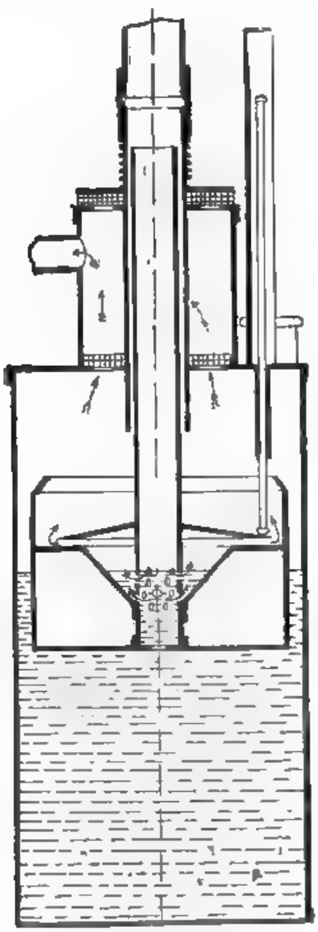


FIG. 151.—The Daimler Filtering Carburetter, used on the early Daimler cycles and carriages.

vessel. At the left-hand upper side of this cylinder was a vent, which was connected with the combustion chamber of the cylinder. The upper cylinder, which is in connection with the combustion

space, has its vents covered with wire gauze, to prevent the ignition of the contained gasoline and vapor.'

When the piston began the suction stroke, air was drawn through this vent, some of it coming through the upper openings already mentioned, and another portion through the vents at the base, which connected it with the main body of the instrument. The air from within this main cylinder was drawn downward to the operating tube, the greater portion of it passing through the small holes in the base of the tube, then upward through the gasoline contained within the central depression of the body of the float, causing vaporization and thoroughly charging the air drawn into the cylinder.

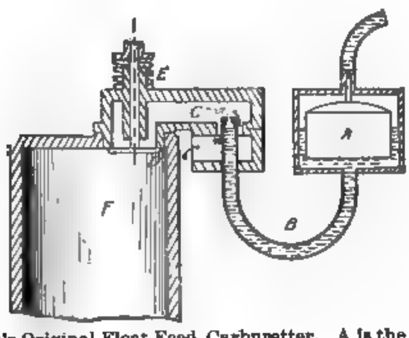



FIG. 152.—Maybach's Original Float Feed Carburetter. A is the hollow float carrying the spindle of the needle valve at its top; B, the tube leading into the inlet valve space; C, the spraying nozzle; D, the inlet valve; E, the inlet valve spring; F, the cylinder space.

**Maybach's Float Carburetter.**—Later vehicle motors made by Daimler used the balanced float feed carburetter invented by his collaborator, William Maybach. As first constructed, this instrument was the simple device shown in the accompanying cut. The float, *A*, contained within a small vessel connected by a tube, *B*, with the valve chamber of the cylinders, *F*, bears upon its upper face the spindle of a needle valve, which regulates the rate at which the gasoline is admitted to the carburetter through the tube shown at its top. The action is obvious: When the piston in the cylinder, *F*, is making its suction stroke, the valve, *D*, is opened inwardly, giving admission to atmospheric air, as

indicated by the arrows. The end of the tube, *B*, which is reduced to form the spraying nozzle, occupies the greater part of the air inlet. A strong spray of liquid gasoline is drawn up by suction and mixes with the atmospheric air in the valve chamber, *C*, the proportions of the mixture being determined by the dimensions of the apertures admitting additional air into the cylinders. Since the float *A*, is not balanced in any manner, its action was liable to be uncertain through the vibrations of travel, with the result that its regulation of the level in the float chamber would be uncertain if the valve stem were not wrenched or broken so as to render the machine useless. Largely from the considerations just noted, later types of the float feed carburetter have been constructed with a very elaborate and reliable adjustment to secure the maintenance of the desired level and the certain action of the needle valve. The method of admitting air to mix with the gasoline spray under suction of the piston has also been so improved as to permit of considerable adjustment of the proportions in the fuel mixture.

**Float Carburetter Development.**—In order to avoid the obvious defects of the first Maybach sprayer, certain constructions have been embodied on all later instruments of this class:

1. Efficient means for balancing the movement of the float; preventing wrenching and breaking of the needle valve spindle, and the disarrangement of the gasoline supply.

2. Reliable devices for regulating the supply of air and gasoline spray from the nozzle, either by original adjustment or by constant variation, by governor or by hand.

**Heating for Carburetters.**—Several makes of sprayer also include means for heating the gasoline feed, either by the hot exhaust gases, or by a water jacket connected to the cylinder circulation system, for the purpose of assisting vaporization. Such a device is not necessary when standard gasoline is used—some authorities declare it to be a "nuisance"—although, as shown later, very useful with alcohol or kerosene.

**Constant-Mixture Sprayers.**—The three types of early sprayer shown in accompanying figures—the Peugeot, Phenix and Longuemare—were used with engines governed on the hit-and-miss, or exhaust-valve-control principle. Consequently, no means was provided for varying the fuel mixture from an original adjustment. Only the Longuemare is provided with a throttling device.

A common feature with these carburetters is an annular hollow metal float, separate from the needle-valve spindle penetrating the

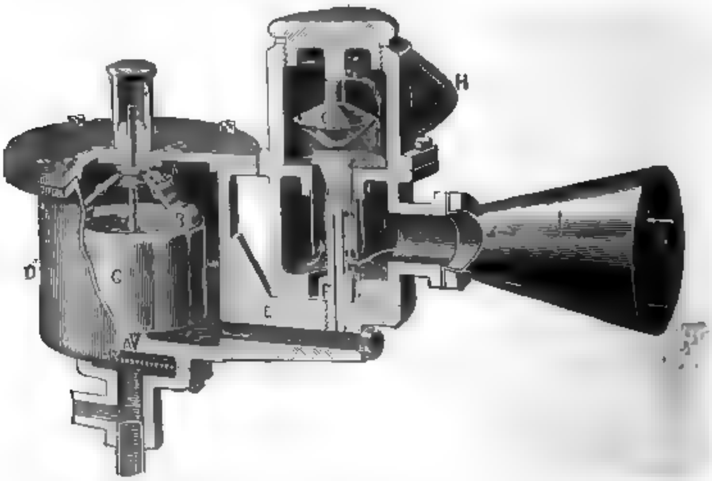



FIG. 153.—The "Phenix" Daimler Carburetter. A is the gasoline needle valve; B, the weighted controlling levers; C, the float; D, the float chamber; E, the gasoline supply tube; F, the spraying nozzle; G, the "mushroom" spray deflector; H, the port leading to the cylinder chamber; I, the air inlet. The air entering the mixing chamber follows the course of the arrows.

eye or central perforation, and actuating it to open the inlet through some arrangement of toggle levers. In the Phenix and Longuemare sprayers the toggle levers carry weights, *BB*, at the free ends of the longer arms, thus providing means for holding open the inlet ports, when the float sinks. In the Peugeot sprayer the weight of the float normally holds the valve open, a weighted collar on the needle spindle alone serving to close it, when the supply of liquid in the chamber is sufficient to raise the float.

**The Phenix Sprayer.**—The Phenix sprayer of Panhard-Levassor had the gasoline inlet at the bottom of the float chamber, and supplied liquid to the spraying nozzle, *F*, through the horizontal tube, *E*. Air entered to the mixing chamber through the cone-shaped inlet, *I*, being regulated by a rotary valve on the base or greatest circumference of the cone. Air is drawn through

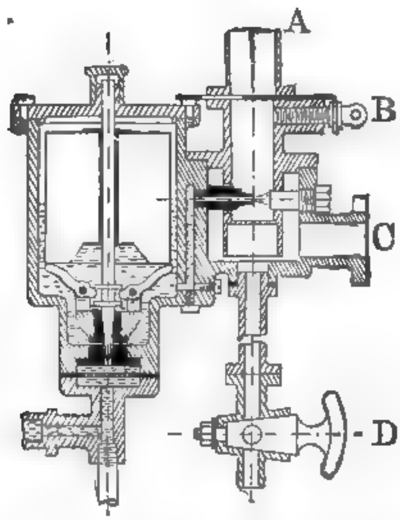



FIG. 154.—Early model of the Peugeot Carburetter. This has many points in common with other carburetters, except that the valve levers are differently arranged; the spraying nozzle at the side of the mixing tube, and the air-inlet from above. A is the air inlet; B, the adjustable air valve; C, outlet vent leading to cylinder; D, adjustable valve for admitting extra air

*I* by suction in the cylinder, which also acts to spray liquid gasoline through the nozzle, *F*. The spray is "broken up" against the mushroom deflector, *G*, which also affords an opportunity for considerable surface evaporation. There is no means, as in some other sprayers, for regulating the feed of gasoline from the nozzle. Its quantity is consequently constant, as regards time of feed and unit force of suction, and the mixture is varied only by adjustment of the quantity of air admitted. The mixture enters the cylinder at *H*.

**The Peugeot Sprayer.**—In the model of Peugeot sprayer, shown in the accompanying section, the gasoline supply is admitted to the float chamber at the bottom, and passes thence to the nozzle through a vertical passage rising to the high level in the float chamber. The air inlet, as shown, is at the top of the vertical tube, which forms the mixing chamber. The amount or proportion of air admitted through this tube may be controlled by a sliding gate valve whose opening is controlled by a hand screw. Extra air, as required, may be admitted through a cock-valve opening into the bottom of the mixing tube, immediately below the outlet to the cylinder.

**The Longuemare Float Feed Sprayer.**—The Longuemare sprayer, shown in an accompanying illustration, is one of the most elaborate variations of the Daimler-Maybach type. The construction and operation of the float chamber and gasoline inlet are obvious. The fuel liquid is supplied to the mixing chamber through a downward vertical tube and through a horizontal tube to the sprayer-atomizer, which rises in the base of the mixing chamber. The mixing chamber shown in connection with this type of sprayer is considerably more elaborate than the one used with the Peugeot just described. The tube, *F*, leads to the combustion chamber of the cylinder, and when the piston is making its suction stroke atmospheric air is drawn through the tube, *E*, passing around the adjustable valve-shaped nozzle leading from the float chamber. This valve-shaped nozzle is of interest in construction, consisting of a head having the general form of a mushroom-valve, on the base of which is a threaded stem, permitting of adjustment in the size of the orifice, through the vertical tube closed by the nutted screw just below the nozzle. The amount of gasoline sprayed out is thus regulated perfectly to any desired limit.

Directly above this valve-nozzle are fixed several layers of wire-gauze, through which the carburetted air passes on its way to the vent, *F*. At the point, *F*, as shown, there are several other layers of wire-gauze. Both series of gauze are indicated by dotted lines across the tubes. Their object is to prevent all danger of explo-

sion, or of disablement, to the instrument in the event of burning-back, which is liable to occur if the inlet valves do not close promptly, or if they should be in any other way disabled. The

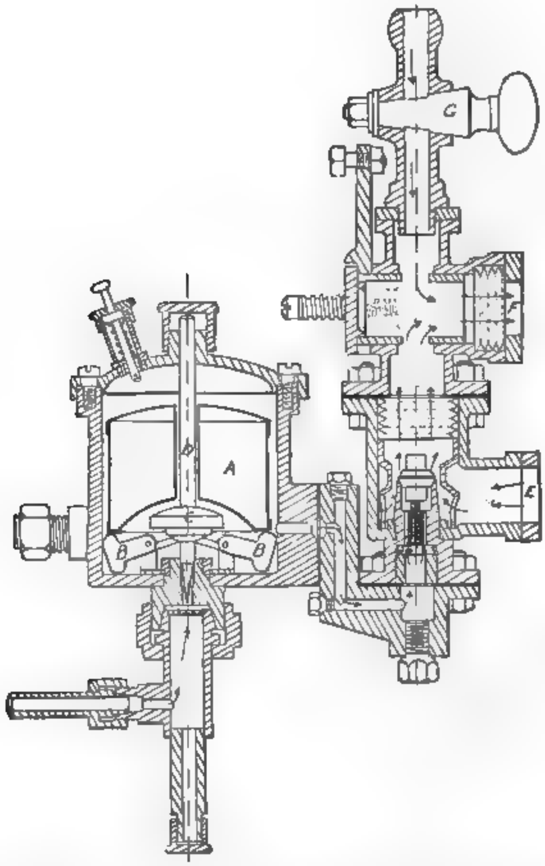



FIG. 155. —An Early Form of the Longuemare Float Feed Carburetter. A is the float; B, B, the weighted levers controlling the needle valve; C, the weight holding the needle valve closed while the lever is right in the float chamber; D, the spindle of the needle valve; E, air inlet; F, pipe communicating to combustion space of cylinder; G, cock for admitting additional air supply.

quantity of air admitted through the inlet port, *E*, is controlled by a valve having the general construction of an ordinary three-way cock, the opening of which is controlled by the upright arm shown just below the cock, *G*. This arm is arranged, as shown,

to be actuated by a link rod, which may come to the driver's hand at a convenient point. It is possible, therefore, to throttle the *volume* of fuel mixture admitted to the cylinder. No means, apart from permanent adjustment of the nozzle valve, as already explained, is provided for varying the mixture to suit the conditions of operation. A larger portion of air, as desired, may be obtained by opening the cock *G*, and admitting the air from above.

**The Duryea Float Sprayer.**—The Duryea sprayer belongs logically in the class of constant-mixture carburetters. Like those described above, it could be used on an engine governed by

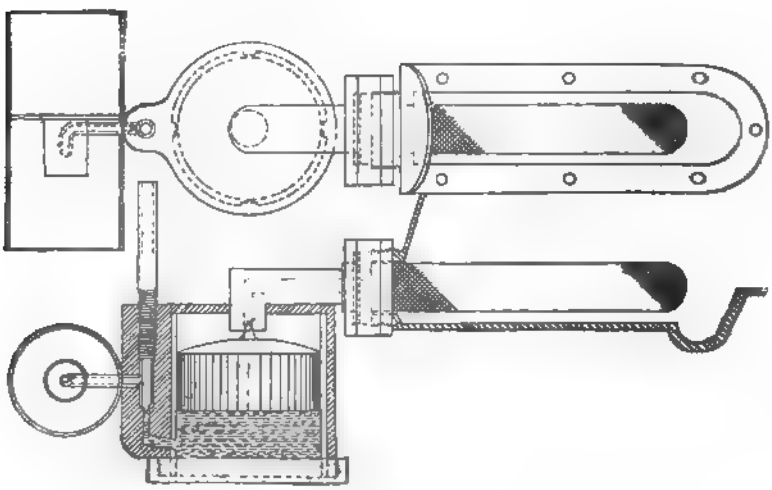


FIG. 156.—The Duryea Float Feed Carburetter or Sprayer.

closure of the exhaust valve, or on one governed by control of the fuel inlet, which is the plan followed with the Duryea engine. "Volume throttling" consists essentially in modifying the opening of the feed pipe, or, as in a few cases, of varying the lift of the valve. The former is the plan followed by Duryea and Mors, the latter that adopted by Winton. A volume throttling carburetter is, of course, a constant-mixture or fixed-adjustment instrument.

In the Duryea sprayer the float, as in the first Maybach instrument, carries the point of the needle-valve secured to its top, thereby closing the entrance of the gasoline from the tank through the top of the float chamber, so long as the proper level is maintained within. Unlike the Maybach sprayer, however, this float is balanced by vertical guides at four points on its circumference, as may be readily understood from the plan and sectional views given herewith. Connected with the float chamber is a vertical tube containing a needle valve for varying the opening, controlled by an adjusting screw, shown in the figure, and which connects to a spraying nozzle, extending into the tube or passage from atmosphere to the combustion chamber of the cylinder. As shown in the plan view, the spraying nozzle is bent around to a right angle at the end and is enclosed in a short length of small diameter tubing. The inflow of air through the larger tube is controlled by a rotary valve, which, with the needle valve in the nozzle, forms the sole means for adjustment. The liquid gasoline is fed to the float chamber from the supply tank through a length of tubing encased in a cylindrical cover of wire-gauze, intended primarily to prevent the passage of any impurities which might interfere with the action of the needle valve or clog the small passages leading to the spraying nozzle.

**Variable-Adjustment Sprayers.**—The majority of modern gasoline engines have sprayers or carburetters that are susceptible of varying the adjustment to suit the constantly changing conditions of operation. In general, there are two varieties of such sprayers:

1. Positively-controlled sprayers.
2. Automatic sprayers.

**Positively-Controlled Sprayers.** — In the former variety variations are effected positively by direct connections to a governor, or to the hand of the driver. In a true throttling sprayer the governor acts to throttle the charge, or reduce the volume of mixture entering the cylinder space, without altering its quality. Very many throttling sprayers, however, regulate

the fuel solely by controlling the quantity of air admitted to the mixing chamber, thus varying the quality of the mixture.

**Automatic Sprayers.**—Automatic sprayers vary the quantity of air admitted, thence, also, the quality of the resulting mixture, by the automatic action of the cylinder suction on an auxiliary air inlet—the amount of air in the mixture being thus increased as the engine speeds up beyond a definite point.

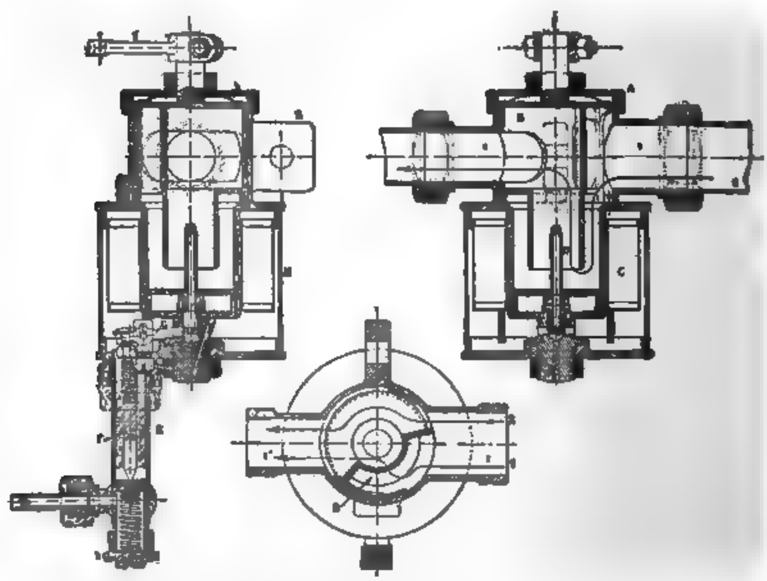


FIG. 157.—The De Dion & Bouton Vaporizer. A is the cover of the air chamber; B the air valve; C, the float; D, the mixing chamber; E gasoline supply; F, gasoline needle valve; G, valve controlling lever. Arrow (1) indicates course of air through mixing chamber; arrow (2), course of additional air through valve B.

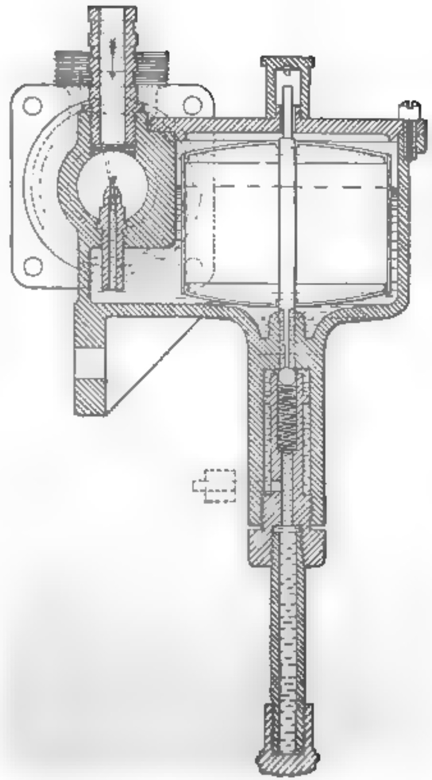
**Combination Sprayers.**—Many recent sprayers, notably the Krebs and Kingston, combine the two principles of positive and automatic control.

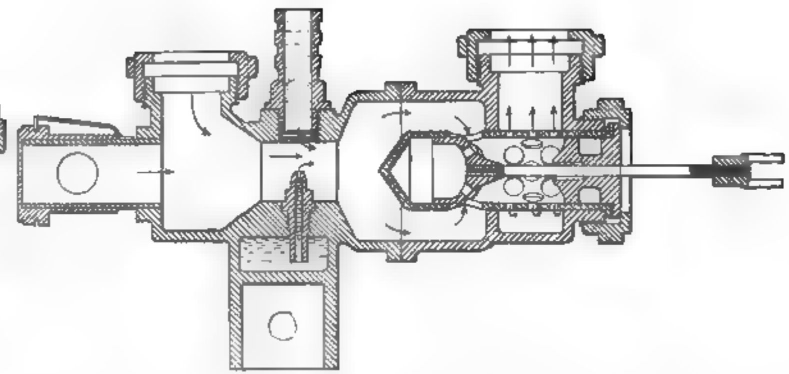
**The De Dion Variable Sprayer.**—One of the earliest of the positively-operated mixers is the De Dion, which is also the prototype of the "self-contained" instruments of its class. As shown in the accompanying sectional plan and elevations, it consists of a

cylindrical chamber, *H,* within which is contained an annular float, *C.* The mixing chamber is set in the centre of the float chamber, the float surrounding it and sliding against its cylindrical walls. The supply of gasoline is admitted to the float chamber through the needle valve, *F,* the opening and flow being controlled by the lever, *G,* which, as shown, is in a raised position, thus allowing the needle-valve to be closed, so long as the weight of the float does not bear upon it. The gasoline is drawn by suction through the nozzle, in the central mixing chamber, by the air entering the tube, *t,* and following the direction indicated by the arrow, marked 1 (one) in the plan and right-hand sectional elevation. As shown in the plan, there is also a cylinder valve, *B,* which may be rotated by the lever, *I,* attached to the stem passing through the cover, *K,* of the upper chamber, *A.* By this handle the fuel mixture may be varied within the desired limits, by regulating the inflow of additional air through the tube, *t,* as indicated by the arrow, marked 2 (two) in the plan.

**The Centaure Sprayer.**—Among the earliest and most efficient of the true throttling sprayers was the Centaure, of Panhard-Levassor, shown in section in accompanying cuts. Unlike many instruments of the float-feet type, it has the valve spindle permanently attached to the float, and balanced at the top, as shown. Instead of the usual needle valve, the lower end of the spindle carries a ball, which is held to its seat by a spring within the gasoline supply tube, so long as there is sufficient liquid within the float chamber to sustain the float. As in other models of sprayer, the gasoline is led to a nozzle, located within the mixing chamber, and is there atomized under suction of air drawn in from the permanent air supply tube, shown to the left and above the nozzle, and, when desired from the variable auxiliary valves, directly over the nozzle and to the extreme left. The inflow of air and gasoline spray is shown by arrows.

To the right of the nozzle, and extending within the mixing chamber, is the strangle tube, within which slides a piston valve through a short length of stroke. As shown in the diagram, this piston is partially drawn forward by the rod worked from the





FIGS. 158 and 159. —Sectional Diagrams of the Centaure Carburetter of Panhard-Levassor. This is the earliest successful governor-controlled carburetting and mixing apparatus. As may be seen, it consists of the usual float chamber and vaporizing nozzle. The float, however, instead of controlling a needle valve, carries a ball on the end of its spindle, which is held close against the inlet port by a tension spring. The liquid spirit is admitted to the supply tube beneath the float chamber, where the short pipe and union nut are shown. The mixing chamber has a port to the left of the spraying nozzle, through which hot air is admitted from the head of the cylinder, as shown in the previous figure of the engine. A constant air supply enters at the port immediately above the nozzle. A variable spring-controlled air inlet is shown at the left. The mixture on its way to the cylinder passes through a perforated cylinder, within which slides a piston, as shown. This piston, slid to the right, closes the inlet admitting a smaller fuel supply. Its rod is attached to the governor slide, and the fuel inlet is thus controlled.

governor slide, or by the hand of the driver. By drawing this piston forward the inlets of mixture to the strangle tube are reduced, and, consequently, a smaller *volume* of fuel is fed to the cylinder. When the piston is drawn out to the full length of its stroke, the fuel feed is entirely cut off, and the operation of the engine is discontinued. In this sprayer the constant air supply was heated, being drawn from a point near the cylinder combustion space.

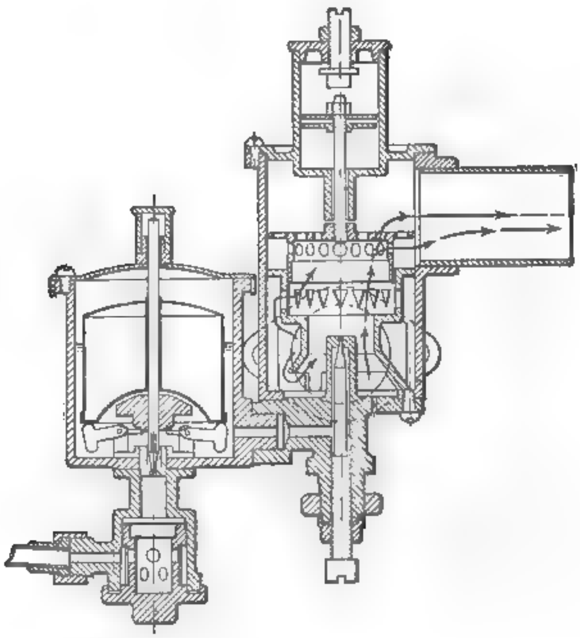


**Fig. 160.—The Pierce Automatic Float-feed Sprayer, with arrows showing course of air through the mixing chamber to cylinder.**

**Automatic Mixers.**—Very many instruments of the automatic type have been produced within the last few years. In virtually all of them the theory of regulation involves a spring-controlled piston valve, which, actuated by the stronger suction of high engine speeds, opens ports for admitting additional supply of air. The advantages of this arrangement are that the uncertainties attending a permanent adjustment of the auxiliary air valves are

overcome, and that the engine takes its own supply, to compensate excessive speeds, as conditions require.

**The Pierce Sprayer.**—The Pierce sprayer is a notable example of automatic instrument, used entirely without positive regulation by hand or centrifugal governor. In general construction it is evidently a variation of the old Longuemare sprayer, having the same mechanism for controlling the gasoline inlet to the float chamber, also an adjustable needle-valve regulation on the spraying nozzle. The air supply port is shown at the rear of the mixing chamber, and air is admitted through a single opening, as shown. The upper portion of the mixing chamber is cylinder-shaped, having V-shaped perforations around its periphery, and within it slides a hollow piston, also having peripheral perforations, as well as vents for the mixture in its upper surface.

This piston is carried on a rod, which, penetrating a stuffing-box on a small cylinder at the top of the instrument, carries another piston, normally held down by a coiled spring. When the engine speeds up to an excessive rate the suction on the first piston is so great as to lift it against the pressure of the coiled spring, thereby opening the V-shaped perforations and admitting additional air. The lift of the piston is predetermined by the adjusting screw at the top of the small cylinder, while its return to normal position, in which the V-shaped ports are closed, is retarded by the resisting action of the upper piston. A perfect dashpot action is thus attained, and swift transitions from maximum to minimum air inlet are thus avoided.

**Spring and Diaphragm Automatic Sprayers.**—Another type of automatic sprayer, now made in several forms, is that having the auxiliary air inlet controlled by coiled spring and diaphragm. Probably the earliest form of this instrument is the Krebs sprayer used by Panhard-Levassor. Its construction and operation may be understood from the accompanying sectional diagram.

**The Krebs Sprayer.**—In this instrument the float chamber, gasoline inlet, etc., are identical with those already shown for the

Centaure sprayer. Gasoline comes from the float chamber through channel, *P*, and spraying nozzle, *L*, air being admitted through port, *K*, passing thence into the mixing chamber, *Q*. The mixture passes thence to the cylinder through the feed tube, *M*, through the port, *N*, whose opening is controlled by the position

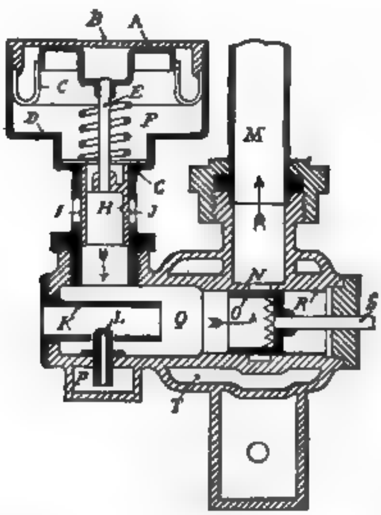



**FIG. 161.—Section of the Krebs Mixer used with the later Panhard-Levassor Engines.** The float chamber and other parts are identical with the Centaure carburetter. Gasoline comes from the float chamber through channel, P, and spraying nozzle, L, air being admitted at K. Q is the mixing chamber from which the air and gasoline gas passes into the feed tube, M, through the port, H, whose opening is controlled by the position of the serrated perforations in piston, O, moving through bore, R, as controlled by the governor through piston rod, S When more air than the fixed quantity admitted at K is required by the conditions of motor operation, the suction of the motor piston depresses the small piston, A, held in cylinder, F, by the spring, E, and sliding in the elastic diaphragm, C. Air is admitted above it through a small port at B. The depression of piston, A, and causes the slide, H, to move downward in tube, G, thus opening to a greater or less degree the ports, J and J, admitting the required amount of air for any given condition.

of piston, *O*, sliding in cylinder, *R;* from the minimum, as shown in the diagram, when the sole exit for the fuel is provided by the points of the V-shaped openings around the periphery of the piston, to the maximum, when the piston is forced all the way to the left (as in the diagram). The impulses of the governor are imparted through piston rod, *S*.

**Krebs Auxiliary Air Feed.**—When more air than the fixed quantity admitted at *K* is required to reduce excessive speeds, the piston, *A*, in cylinder, *F*, is depressed by engine suction against the tension of coiled spring, *E;* thus, according to the force of the suction, opening the auxiliary air valves, through the hollow piston valve, *H*, and Y-shaped ports, *J, J*, in the piston, *G*.

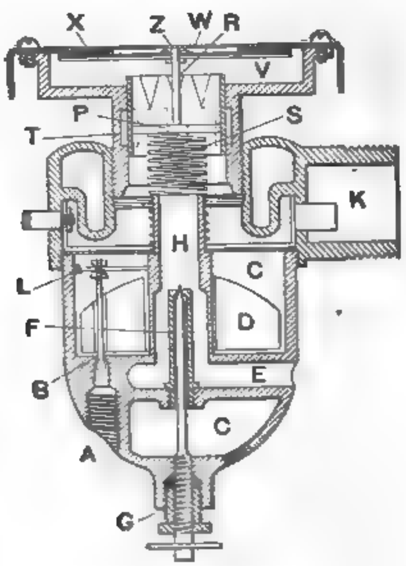



FIG. 162.—The "Acorn" Automatic Float-feed Sprayer.

To the periphery of piston, *A*, and cylinder, *F*, is attached a flexible diaphragm, *C*, which, forming a kind of sucker behind it, admitting air slowly through a small port at *B*, retards the movement of *A*, and the opening and closing of the ports, *J, J*, and preventing too sudden transitions between the maximum and minimum of power effect.

**American Automatic Sprayers.**—Several recent American sprayers operate on the same principles as the Krebs, in so far as

concerns the aspiration of additional air. Among these are the Acorn and the Kingston Automatic, both worthy of notice as types of their class.

**The Acorn Sprayer.**—In the Acorn sprayer the gasoline is fed through port, *A*, through ball valve, *B*, into the annular chamber, *C*, containing the annular float, *D*. The ball valve is closed when the float, *D*, rises against the long-armed lever, *L*. Air is admitted through port, *E*, under suction of the engine piston, and atomizes the liquid gasoline at nozzle, *F*, regulated by the adjustable needle-valve, *G*. Fuel mixture passes to the cylinder space through tubes, *H* and *K*.

**The Auxiliary Air Feed.**—When the engine operates at excessive speeds, the suction increases to such a point that piston valve, *P*, is drawn down against the pressure of spring, *S*, allowing additional air to enter the mixing chamber through ports, *I*, and V-shaped slits, *V*. Piston, *P*, carries on its rear face a rod, *R*, which is attached to a diaphragm, *W*. Between this diaphragm and the top of the instrument is an accordeon-folded leather piece, *X*, which operates as a sucker when the piston is drawn downward; drawing in a small quantity of air through an orifice at *Z*. As in the Krebs sprayer, the effect of a dashpot is thus obtained to retard the movements of the diaphragm.

**The Kingston Automatic Sprayer.**—Precisely similar in operative effect is the Kingston automatic sprayer. Here the gasoline is admitted through supply tube, *G*, and ball valve, *B*, to the float chamber, in which is a U-shaped cork float covered with thin sheet copper. From this chamber the liquid is led out through nozzle, *T*, regulated by adjustable needle-valve, *A*. Air for the mixture is admitted through port, *I*, and around mushroom valve, *V*, whose clearance is permanently adjusted by screw, *C*, as indicated, and is fed to the cylinder space through port, *H*, whose opening is controlled by a damper valve, actuated by the lever, *L*.

**The Auxiliary Air Feed.**—As the suction of the engine piston becomes stronger, valve, *V*, is drawn further from its seat against the pressure of spring, *S*, and, as in the types of instrument previously noticed, the diaphragm, *D*, is also drawn downward, obtaining a sucker action by the slow admission of air through the adjustable opening at *F*. By this means the dashpot effect is obtained.

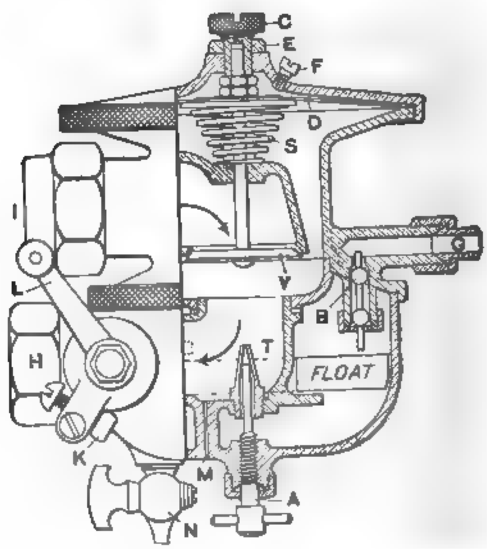



FIG. 163.—The "Kingston" Automatic Float-feed Sprayer.

**The Winton Variable Carburetter.**—The Winton carburetter, used in connection with the famous pneumatic control, operates in a manner distinctly analogous to that of the sprayers just described. A marked difference, however, lies in the fact that engine control is attained by restricting the lift of the inlet valve, rather than by drawing in additional air. It is, therefore, a volume throttler, the relative proportions of air and gasoline being always maintained at a fixed point, as will be explained in connection with Fig. 214

On the inlet valve in the carburetter is a small plunger, fitting into the cylinder to the right of spring, *S*, in the section of the carburetter, and between it and the inlet valve is a bushing that acts as a stuffing box. The air pressure leads to this small cylinder, and unless the pressure is reduced by opening the relief valve, there is no chance for the inlet valve to unseat and admit to the engine cylinder a charge of gas. On the extremity of the inlet valve is placed a conical needle-valve, the taper of which is so proportioned that a lift of the inlet valve, allowing a certain volume of air to pass into the carburetter, will unseat the needle-valve to admit into the carburetter a proper quantity of gasoline which, vaporizing and mixing with the air, produces the correct explosive mixture; consequently, no matter how great or how small the charge entering the cylinder, the quality of the mixture remains uniform. Judged from this feature of operation, the Winton carburetter is also analogous to the surface mixing valves next to be explained.

**Surface Mixing Valves.**—The surface carburetter for vehicle engines is found principally in the form of the familiar mixing valves. Among the earlier examples of this type of instrument was the Huzelstein carburetter, which seems to have been the prototype for the James-Lunkenheimer and several other mixers.

**The Huzelstein Valve Carburetter.**—The Huzelstein, or "Universal" carburetter consists of a vertical cylindrical chamber. Within this is a mushroom valve controlled by a coiled spring and hung on a spindle, the upper end of which forms a needle-valve, closing the inlet port for liquid gasoline, shown at the top of the cylindrical chamber. The gasoline from the supply tank is fed through a tube, *A*, leading to this chamber and having its rate of supply regulated by an adjustable screw, *B*. Connection with the interior of the chamber and the combustion space of the cylinder is had by the tube, *C*. The tube, *D*, is also connected with the combustion space so as to permit the heated products of combustion to circulate through the jacket or passage around the upper part of the mixing chamber above the valve. The suction

of the piston operates to open the valve, drawing it from its seat and depressing the spring around the lower portion of the valve spindle. This, of course, opens the needle-valve leading from the gasoline feed pipe and permits the inflow of a small quantity of liquid gasoline, which is mixed with the air drawn through the

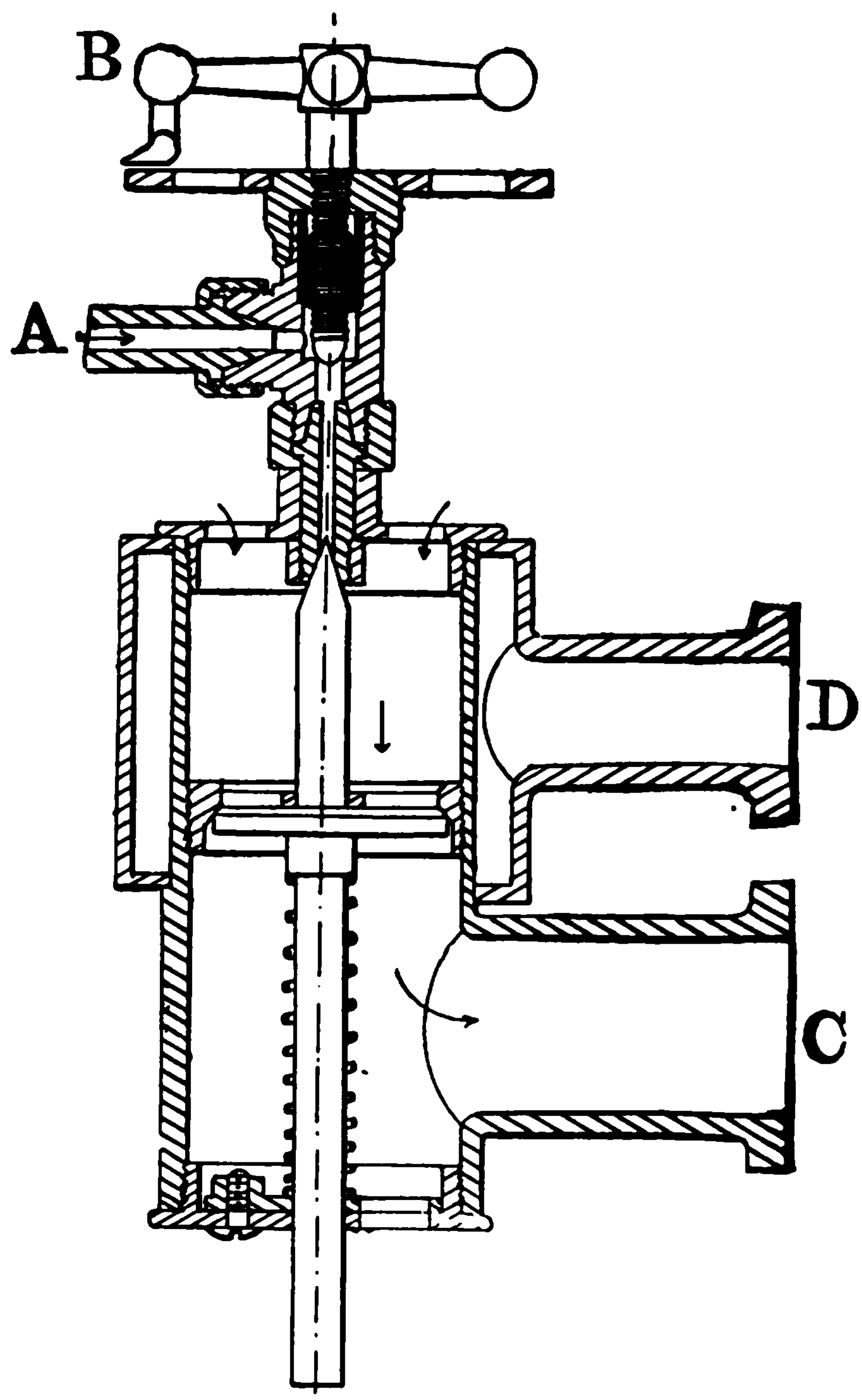



FIG. 164.—The Huzelstein Carburetter. A is the inlet for gasoline; B, the valve controlling inlet; C, the tube leading to cylinder combustion space; D, tube for leading hot exhaust gases around the jacket on the mixing chamber. Arrows indicate entrance for air and course of mixture to cylinder.

opening indicated by the arrows at the top of the chamber. The mixture is perfected by the heat of the vapors passing through the tube, *D*, and around the jacket connected with it; also, by the friction in passing through the narrow clearance between the open valve and its seat. Between the periodic suction strokes of the piston, the air in the upper portion of the mixing chamber above

the valve is made to absorb some of the heat circulating around it. and hence, according to the theory of the inventor, is better prepared to mix perfectly with the gasoline vapor.

**The James-Lunkenheimer Valve.** — Several well-known makes of American carburetters are constructed to operate along the same general lines as the Huzelstein. Among these we may mention the James mixing valve, shown herewith. This device consists of a valve chamber having three openings or vents: one for the admission of air, another for the admission of liquid gasoline in small quantities, a third as exit to the cylinder combustion

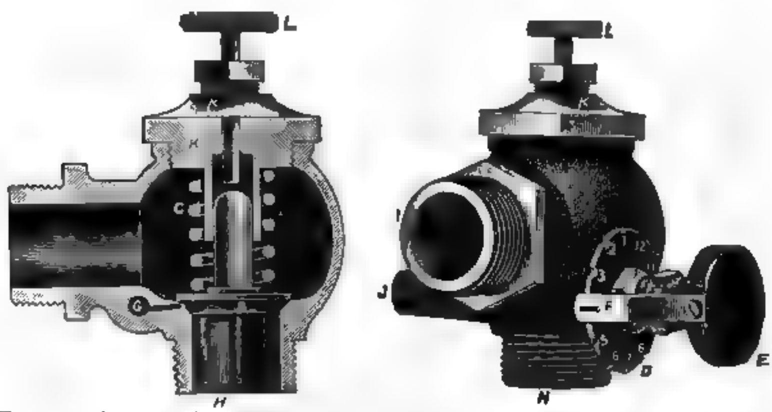



FIG. 165.—The James-Lunkenheimer Improved Mixing Valve. B. fuel inlet valve; C, spring controlling B; E, the wheel controlling gasoline valve; F, clip or top for holding E in position; G, gasoline supply tube; H, air inlet; I, entrance to cylinder; J, entrance for gasoline; K, cover of valve chamber; wheel and spindle controlling tension of spring, C.

space. The air port is controlled by the mushroom valve, on the seat of which the gasoline feed opens. The passage, *I*, is connected direct to the combustion chamber of the cylinder, and at the suction stroke of the piston, the air is drawn through the tube, *H*, its pressure causing the valve, *B*, to rise from its seat. The air drawn through the passage, *H*, also draws as spray a small portion of liquid gasoline through the tube, *G*, which connects through the passage, *J*, with the gasoline supply tank, thus securing a very good fuel mixture, according as the play of the valve, *B*, and the opening of the tube, *G*, are adjusted. The

proportionate amount of gasoline fed into the cylinder through the passage, *J*, of the tube, *G*, is controlled by a needle-valve carried on the spindle at the hand-wheel, *E*, the proportionate opening of the valve being indicated on the graduated disc, *D*, by the position of the clip, *F*. The play of the valve is also regulated by the position of the spindle carried on the hand-wheel, *L*, which is threaded so as to be raised or lowered as required. The tension of the valve spring is regulated by screw, *K*.

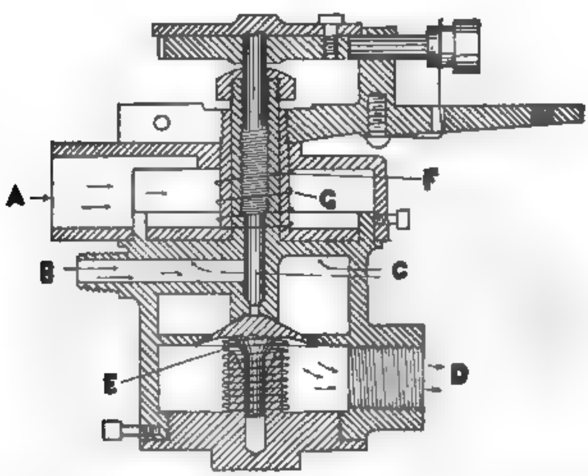



FIG. 166.—Sectional Diagram of the Haynes-Apperson Throttling Mixer. A, air inlet; B, gasoline inlet; C, C, location of air ports into mixing chamber; D, vapor exit to engine. E, mushroom valve held on seat by spring, opened by suction of engine piston; F, threaded needle valve spindle; G spring for raising upper member of air chamber when released by screw motion of the levers attached to cover retaining screw and needle valve spindle, both being raised or lowered by the same movement.

**The Haynes Mixer.**—The form of mixing valve long used with the Haynes vehicle engines is, according to claims, a peculiarly sensitive instrument, permitting exact adjustments of the mixture for any operative requirements between 135 and 1,600 revolutions per minute of the engine fly-wheel. It consists essentially of a mushroom valve of unusually conical shape, arranged to open against a coiled spring under suction of the engine piston and allowing gasoline to enter the combustion space

through a needle-valve, and air through a variable inlet chamber. The spindle of the needle-valve is threaded, so that its lift may be regulated by rotary movement, screwing or unscrewing in its socket. The air inlet chamber may be varied in size and inlet capacity by a cylindrical cover held in place against the tension of a coiled spring around a sleeve slid over the needle-valve housing. This sleeve is also threaded above the top of the air chamber cover, so that a lever worked in a rotary direction by the throttling link may allow the cover to rise or lower, as the necessity occurs for reducing the supply of air for the mixture. Since the same lever handle controls the lift of the needle-valve and of the air chamber cover, the proportions of air and gasoline vapor may be maintained within moderately fixed limits. The opening of the needle-valve may be varied from a few thousandths of an inch upward, within limits, and only a very slight movement of the stem suffices to increase the gas supply or shut it off entirely. The throttle is operated by a foot button coming through the floor before the driver's seat.

**Other Fuels than Gasoline.**—The internal-combustion engine, as applied to the propulsion of a motor vehicle is commonly known as the "gasoline engine" in the United States, and as the "petrol engine" in England. This is because it generally uses gasoline vapor as its fuel. As a matter of fact, several other substances are suitable as fuel, among them being kerosene and alcohol. It would also be possible to operate a vehicle engine with producer gas, generated in a "suction producer," in which air is drawn through a body of burning charcoal, coke, anthracite or other carbon. Something has also been done in the direction of using acetylene, but the common opinion seems to be that this gas is generally unreliable and frequently dangerous.

Producer gas would be altogether the cheapest form of engine fuel, but its successful use would involve a larger engine content per unit of power delivered, and also a proportionally greater area of cooling surface. It will probably see some use in the future particularly on commercial vehicles.

**Denatured Alcohol.**—The removal of the tax on denatured alcohol will have, according to some opinions, a decidedly beneficial effect on the automobile industry. It is a fuel that may, under favorable circumstances, be very cheaply manufactured. It is also cleaner and less dangerous than gasoline, although possessing a smaller heat-equivalent.

Denatured alcohol is merely ethyl spirit, or the common spirit of wine, mixed with methyl alcohol, or wood spirit, and some other hydrocarbon. The object of mingling the spirit with the other

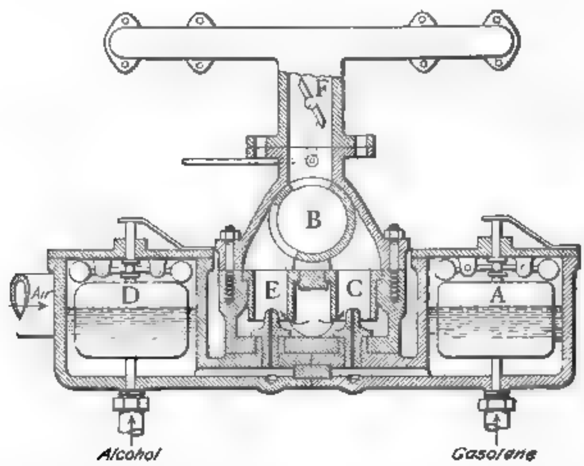



FIG. 167.—A Double Float-feed Carburetter for alcohol and gasoline. A, float in gasoline chamber; B, rotary valve controlling outlet of alcohol or gasoline to engine space, through nozzles, C or E; D, float in alcohol chamber; F, butterfly valve for controlling volume of fuel charge.

ingredients is to prevent its being drunk. Denaturization may be complete or incomplete. In the former case the mixture is useful only for fuel; in the latter it may be utilized in other industrial processes. A common formula for complete denaturization, as used in Germany consists in mingling 2½ liters of a "denaturizer,"

Wood Alcohol........................ 4 parts,
Pyridin ............................ 1 part,

with each 100 liters (26½ gallons) of alcohol spirit. Incomplete denaturization may be achieved by mingling 5 liters of wood

alcohol and ½ liter pyridin, or 10 liters of sulphuric ether, or 1 liter of benzol, or ½ liter of oil of turpentine, with each 100 liters of alcohol. According to various authorities a common mixture for engine fuel consists of 10 volumes of 90% methyl spirit and ½ a volume of some other hydrocarbon to each 100 volumes of 90% ethyl alcohol.

**Conditions of Using Alcohol Fuel.**—The successful use of alcohol as a fuel for a gas engine involves the following conditions:

1. For complete vaporization of the alcohol heat is necessary. For this reason the carburetter is frequently heated by the exhaust or by water jacketing. One type of alcohol carburetter, shown in Fig. 167, is double, the engine being started with gasoline, and run with alcohol as soon as the speed is sufficient to generate a high temperature. The alcohol is then turned on by the rotary cock valve, B.

2. A higher compression than is commonly used with gasoline is necessary, in order to obtain as high a power-efficiency as possible.

3. Reliable sparking devices are essential, in order to produce complete combustion, preventing injurious acid products liable to result from water vapors and incomplete combustion.

The power-efficiency of alcohol has been given as slightly over 1 pint per horse-power, according to purity. The figure for gasoline is generally given as about .86 pint per horse-power. An interesting test of power-efficiency was recently made with a motor vehicle used for dragging a plow. With 2 gallons of gasoline 3 roods were plowed; with 2 gallons of kerosene, 3 roods, 35 poles; with 2 gallons of alcohol. 2 roods, 25 poles.

## CHAPTER TWENTY-FIVE.

### METHODS OF IGNITING THE CHARGE IN THE CYLINDER OF A GAS ENGINE.

**Varieties of Ignition Apparatus.**—There are several methods of igniting the fuel charge in the cylinder of an internal-combustion engine. Among them may be mentioned the following:

1. *Ignition by the heat of compression,* as in the Diesel engine, where fuel gas is fed to the cylinder unmixed with air; is compressed by the instroke of the piston, and is ignited by the inrush of air, separately compressed to a temperature of nearly 1,000 degrees, and admitted to the cylinder at the end of the compression stroke. This requires a separate air-compressing cylinder.

2. *Ignition by hot head,* as in the Hornsby-Akroyd oil engine, where oil is atomized into a chamber, connected to the combustion space by a short tubular passage, and air is fed into the cylinder through a poppet valve. The oil chamber is heated to a high temperature by a torch or other form of burner, and ignition takes place when air is forced in under the impulse of the piston instroke. After a few strokes and ignitions, the heat generated in the unjacketed walls of the oil chamber is sufficient to fire charges so long as the engine is in operation.

3. *Ignition by catalysis,* which consists in forcing the fuel mixture under the stroke of compression into a piece of spongy platinum in the combustion space. The platinum is heated by compression to a temperature sufficient to fire the charge. Ignition by catalysis has been tried to some extent, and, according to reports of experimenters, seems to promise practical results in the future. It is not as yet an established method in gas-engine ignition.

4. *Ignition by Incandescent Tube.*
5. *Ignition by Primary Electric Spark.*
6. *Ignition by Secondary Electric Spark.*

**Ignition for Automobile Engines.**—Of these six methods of ignition only three—the hot tube, the break-contact spark, and the jump-spark—are at all significant in automobile practice. In the early forms of carriage engine, as built by Daimler and his French collaborators, the hot tube was used exclusively. At the present time, however, the two varieties of electric spark ignition divide the favors.

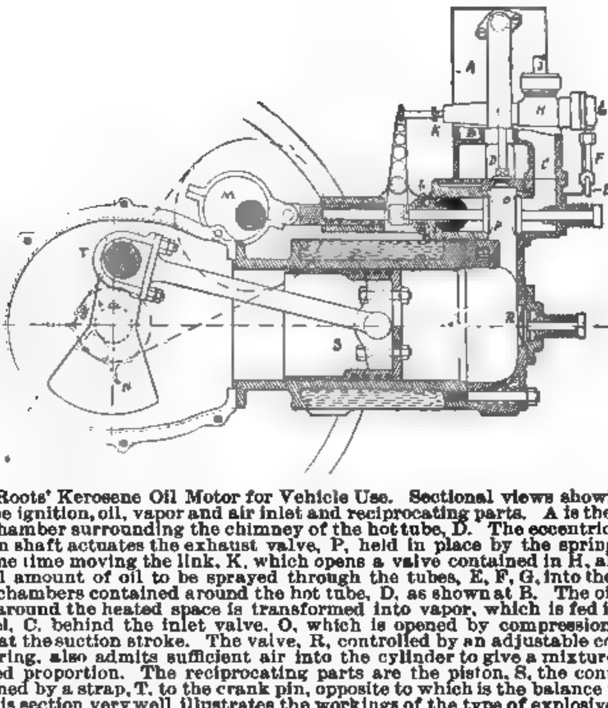



FIG. 163. Roots' Kerosene Oil Motor for Vehicle Use. Sectional views showing the hot tube ignition, oil, vapor and air inlet and reciprocating parts. A is the vaporizing chamber surrounding the chimney of the hot tube, D. The eccentric, M, on the cam shaft actuates the exhaust valve, P, held in place by the spring, L, at the same time moving the link, K, which opens a valve contained in H, allowing a small amount of oil to be sprayed through the tubes, E, F, G, into the circulating chambers contained around the hot tube, D, as shown at B. The oil circulating around the heated space is transformed into vapor, which is fed into the channel, C, behind the inlet valve, O, which is opened by compression of its spring at the suction stroke. The valve, R, controlled by an adjustable compression spring, also admits sufficient air into the cylinder to give a mixture of the required proportion. The reciprocating parts are the piston, S, the connecting rod joined by a strap, T, to the crank pin, opposite to which is the balance weight, N. This section very well illustrates the workings of the type of explosive motor using hot tube ignition

**Ignition by Incandescent Tube.**—In this form of ignition a blind tube of platinum and porcelain is screwed into the wall of the cylinder, so that its open end is continuous with the combustion chamber, as shown in the sectional diagram of the Roots oil engine. Around and against this tube the flame of a separately supplied gas burner is allowed to play, thus producing the re-

quired temperature for explosion. With some engines using hot tube ignition, the connection with the cylinder is controlled by a slide-valve, which is positively operated, so as to open and admit the compressed mixture at the proper point in the cycle. With

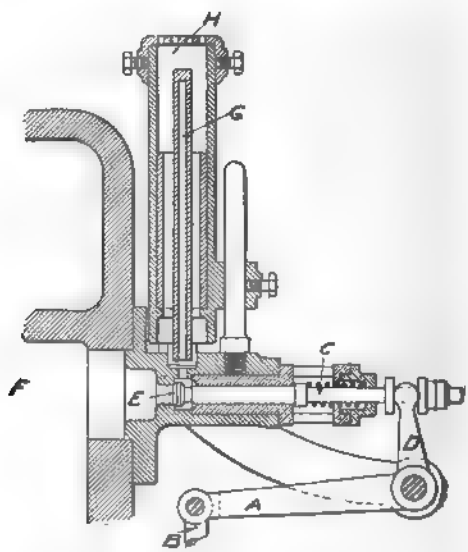



FIG. 169.—A Hot Tube Igniter, with a Geared Timing Attachment for Regulating the Point of Firing. G is the hot tube enclosed with a cylindrical case having a perforated cap, H, at the top. The heat of the tube is maintained by a gas flame within the cylindrical case. The link, B, operates the levers, A and D, so as to open the valve, E, which is normally held closed by the spring, C, bearing on its rod as shown. In opening the valve to the point in the cycle at which the cam actuates the link, B, thus compressing the spring, C, and opening the valve, D, the interior of the hot tube, G, is brought into communication with the combustion chamber, F, of the cylinder. The time of ignition may be varied by adjusting the throw of the cam, so as to bring the opening of the valve, E, to any desired point.

others, there is no valve whatever, the act of compression alone operating to force the mixture into the tube and begin the process of ignition at or shortly before the end of the compression stroke.

**Time Ignition with an Incandescent Tube.**—To arrange the tube to open into the combustion space without a valve involves the difficulty of occasionally causing premature ignition, and is inferior to a well-geared device for timing the moment of ignition. Accordingly, a "timing valve," such as is shown in an accompany-

ing figure, positively operated from the cam-shaft, has been used with some gas engines. In this device, the valve, *E,* is held open throughout the firing and exhaust strokes of the piston, so that it may be swept clean of the burned-out gases contained within it. Upon the completion of the exhaust stroke it is closed, and so remains until, at the predetermined point in the cycle, the push rod is again actuated from the cam-shaft.

**Troubles with Hot-Tube Ignition.**—There are several serious objections to the hot-tube :

1. It will cause misfires, when filled with burned gases, that prevent the fresh fuel charge from coming into contact with the incandescent walls.

2. It will cause premature ignition, when the heated portion is too near the combustion space of the cylinder, and the rest of the tube is clogged with burned gases.

In order to obtain the best results with an incandescent tube several things are necessary:

1. The burner flame should play upon the tube as nearly as possible at the middle point of its length.

2. The heat of the flame should be carefully maintained at the point found most suitable for rapid ignition, coupled with the rapid expulsion of the burned gases under their own expansive energy.

3. The tube should be of dimensions found most suitable for forcing the fuel gas into its interior at the proper moment for ignition.

Apart from faults of construction and adjustment, the most common troubles with tube ignition arise from:

1. Cracked tubes.
2. Loose or faulty burners.
3. Faulty supply of fuel to the burner.

**Ignition by Electric Spark.**—Electric spark ignition is now in practically universal use. It possesses the advantage of providing an entirely intermittent source of ignition, and of being much more flexible than any constantly existing supply of heat, thus being susceptible of nearly perfect timing. For the generation of current it requires some source of electrical energy, such as a battery of galvanic cells, a small dynamo, or a magneto-generator. The current produces a spark, either from a primary or a secondary circuit; the former containing an ordinary reaction coil and producing a low-tension spark, from either a wiping or a breaking contact; the latter containing an induction coil and producing a high-tension spark between slightly separated terminal points, which is commonly known as the "jump-spark." The sparks of both varieties are successfully used in motor carriages, although the high-tension circuit with the jump-spark seems to be the favorite.

**Sources of Current for Ignition.**—There are four sources of sparking current in common use:

1. Primary cell batteries.
2. Secondary, or storage cell batteries.
3. Magneto-generators.
4. Small dynamos.

No other means of current generation has been used, although one recent inventor proposes to supply current from a thermopile in the muffler.

**Primary Cell Batteries.**—Primary sparking batteries generally consist of between four and six open-circuit dry cells in series, giving a pressure of between 1 and 1½ volts per cell. Two such batteries are generally included in the outfit, either of them being switched into circuit, as required, or both being connected in multiple, to give a greater current at the same voltage. In many cases the chemical battery is used only for sparking at the start of the engine, and until the magneto or dynamo has attained sufficient speed for continuous effect, being then auto-

matically switched out of circuit. It is necessary to use the open-circuit type of cell, since the current must be periodically interrupted, as will be presently explained.

**Storage Batteries.**—With several makes of carriage, particularly such as are driven by high-powered motors, small storage cells are used as a source of current. The size most effective for this work is the 40 ampere-hour, which furnishes current

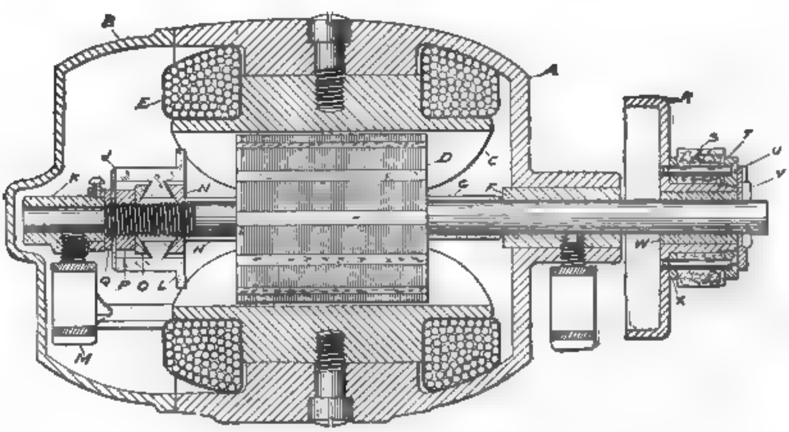


FIG. 170.—Sectional Diagram of the Apple Igniting Dynamo. The parts shown are: A, cast iron body containing the moving parts; B, the hinged lid of the body; C, the one pole piece of one of the field magnets; F, brass bearing of the armature spindle; G and H, fibre tubes surrounding the spindle; K, brass spider supporting the spindle; L, commutator; M, wick feed oil cup; N, beveled nut supporting the commutator; O, P, Q, supports of the commutator; R, the driving disc; S, lever friction pinion. This machine can generate a direct current at 8 volts at a speed of between 1,000 and 1,200 revolutions per minute. It is provided with a simple centrifugal governor that automatically interrupts the driving connections when a certain speed has been exceeded.

sufficient, either for the continuous ignition of the motor or for starting, with a small dynamo or magneto, being then cut out by an automatic switch. As the general theory, construction and management of storage batteries are outlined in a later chapter, it will be necessary to say little here regarding them. The fact that a storage cell must be periodically charged from a source of direct current renders its use somewhat more troublesome than that of a primary cell. It has the great advantage, however, that,

unlike any type of primary cell, it may be renewed or recharged when the current gives out. When a direct current is available from street lighting or power mains, no switchboard or rotary converter is required for charging, as is necessary with the batteries used in propelling electric carriages.

**Magneto-Generators and Dynamos.**—With gasoline engines ignited by a primary spark, the source of electrical energy, except

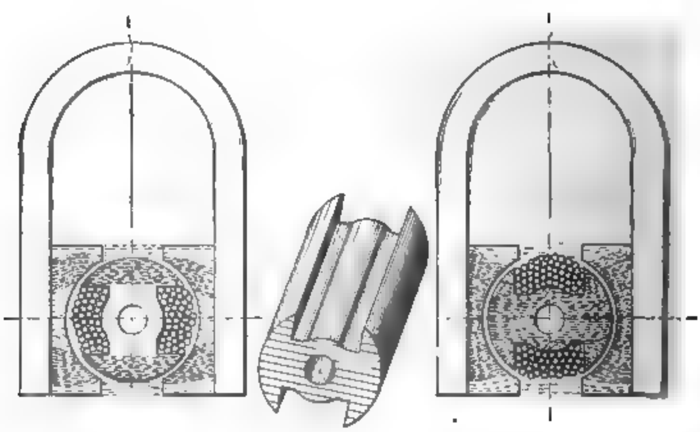


FIG. 171.—Diagram of the Construction and Theoretical Operation of a Typical Magneto-Generator. Between the prongs of the horseshoe magnets, the shuttle-shaped armature, shown at the centre of the figure, rotates on a suitable spindle. This armature is wound from end to end with insulated wire, so that when rotated a powerful current is produced in the windings by cutting the magnetic lines, whose varying strength is shown by the shaded portions in the two views. When the armature is in the position shown in the first diagram, the lines of force mostly converge at the top and bottom, finding a direct path through the metal and flanges of the shuttle. When in the position shown in the second diagram, the lines are converged so as to pass through the metallic core of the armature; the most direct path being chosen in both cases.

in starting, is generally a magneto-generator. The primary distinction between this form of electrical source and a dynamo, as the words are generally used, is that the magneto-generator has a permanent magnetic field, composed of several permanent magnets, while a dynamo has a separately excited magnetic field, consisting of an even number of pole pieces or cores, wound with insulated wire, and connected in series throughout the entire circuit of the field. Between the ***es rotates an armature con-

sisting of a drum or bar, wound about with an insulated wire, the two terminals being connected through the commutator to the outside circuit, which begins and ends at the commutator brushes.

**The Operation of a Magneto-Generator.**—The magneto-generator consists of two or more horse-shoe magnets set in suitable pole pieces, between which rotates a shuttle-shaped armature, with transverse section like the letter H, wound from end to end with fine insulated wire As may be seen in the accompany-

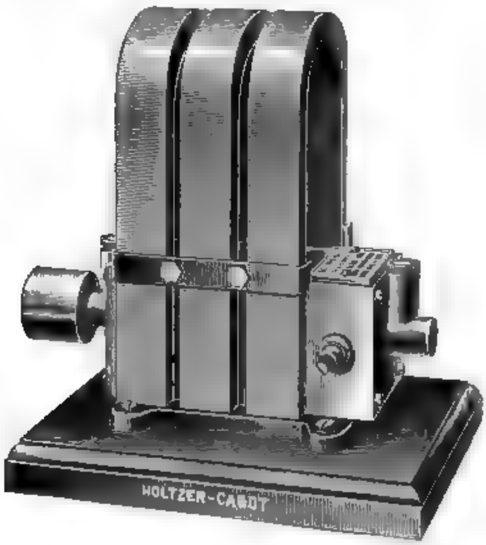



FIG. 172.

FIG. 172A.

FIGS. 172 and 172A.—A Typical Magneto-Generator—the Holtzer-Cabot Vertical Standard, and Current-Collecting Brush.

ing illustration, the lines of force extending between the poles of the magnets are variously distributed according to the position of the armature in its rotation. This is true because the magnetic lines of force pass more readily through the flaring portion of the iron case—the sides of the H—than through the winding laid between them. Any movement of the armature on its spindle, either in making a complete revolution or in oscillating backward and forward, must operate to deflect and distort these lines of force in such a manner as to set up powerful induced currents in

the armature winding. Since, however, the lines of the magnetic forces are thus continually shifted from the path of the least resistance to the path of the greatest resistance, it follows that the current delivered from the terminal connections will constantly shift its potential, and will hence be an alternating current—that is to say, a current flowing first in one direction and then in another.

**Alternating and Direct-Current Magnetos.**—When an alternating current is to be taken from a magneto-generator, as in telephone circuits, etc., one end of the armature winding is connected to the centre of the rotating spindle, which is insulated; the other, to the frame of the machine. Generators so constructed and wired may be used for gas-engine ignition, provided the cut-off of the current be timed to occur at precisely the point of highest potential or greatest intensity, which is to say, when the longitudinal flange pieces of the shuttle-shaped armature are in a vertical position, as shown in accompanying diagrams. This involves, of course, that the armature be rotated at a certain definite speed, and that the point of ignition is changed with any variation in the speed. It also involves that the time of the spark would be varied by changing the position of the field pieces—advanced by tipping the magnets in the direction *opposite* to rotation, retarded by tipping them in the *same* direction. For ordinary ignition circuits, however, the alternating current is not used, and consequently the magneto is equipped with a rotating commutator and terminal brushes, such as are used on direct-current dynamos.

**The Operation of a Magneto-Generator.**—The general operation of the magneto-generator depends upon a few obvious principles of construction, which we may sum up under the following heads:

1. The quantity of the current depends upon the strength of the magnetic field and the number of lines of force passing through the armature.

2. The electromotive force produced depends for its amount upon the length of the armature winding, and the rapidity with which the armature is rotated, cutting and deflecting the lines of magnetic force.

3. If the armature be wound with comparatively thick wire, which would give a short winding, the E. M. F. will be low; but if it be wound with a finer wire, giving a much greater length, the E. M. F. will be higher, in ratio to the diameters of the wires used.

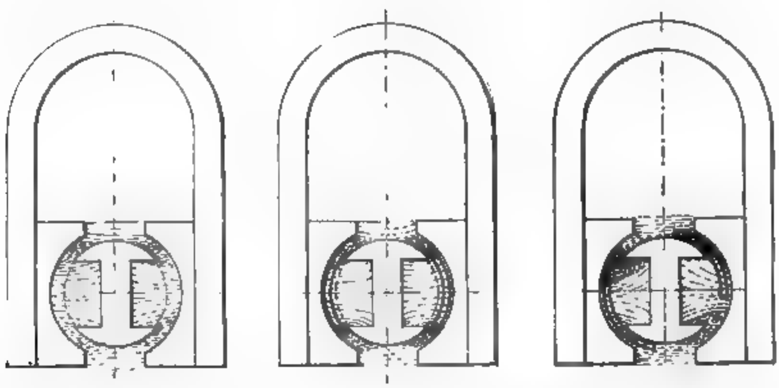


FIG. 173.—Diagram of the Construction and Operation of the Simms-Bosch Igniting Magneto. In this machine the armature is stationary, the lines being cut by an open sleeve rotating between it and the field pieces. The first diagram shows the convergence of the lines of force before the rotating sleeve has been inserted; the second shows the lines where the sleeve is directly across the magnetic lines; the third, where the sleeve is in position at oblique angles to the lines. As may be understood, this arrangement produces a very powerful variation of the field and a very strong output of E. M. F.

**A Stationary Armature Magneto-Generator.** — Although most of the magneto-generators manufactured for use in igniting gas engines conform to the general characteristics of the machines just described, an interesting variation is found in the Bosch & Simms stationary armature generator for primary spark circuits, which operates without a commutator, the terminals being connected to the outside circuit, as in the ordinary telephone magneto. The armature of this machine is shuttle-shaped and wound with insulated wire, as already described, but it is fixed rigid at one end in such position that the lines of magnetic force strike directly through the insulated coil of the winding. The armature, however, is of somewhat smaller relative diameter than

is used on the other types of magnetos, in order to leave a clearance for an intervening sleeve or open-sided cylinder of soft iron, which is oscillated on the same axis between it and the pole pieces through about one-half a revolution. Motion is imparted to the oscillating sleeve by a connecting rod and crank geared on the second shaft of the engine, the difference in throw between the

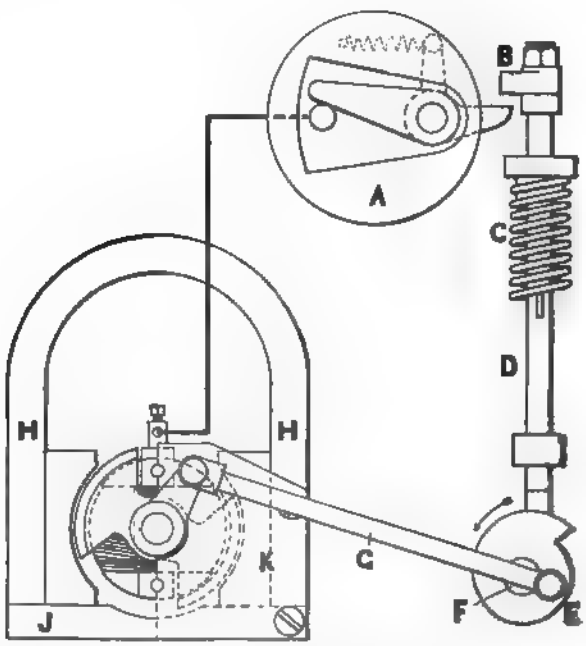



FIG. 174.—Diagram of the Simms Magneto and Primary Sparking Circuit. A is the metal base mounting the sparking contacts; B. a hammer head on rod, D, for actuating bell crank against tension of spring, separating electrodes; E, rotating notched cam on shaft, F; G, connecting rod for oscillating sleeve let over armature; H, H, magnets; K. pole piece; J, base plate of magnets.

crank on the spindle of the sleeve and that on the second shaft operating to prevent a full revolution of the sleeve. A drop cam on the second shaft breaks the circuit at the contact points within the cylinder and makes a spark at a predetermined point in the stroke, which always occurs at precisely the time when the oscillating sleeve is in position to cut through the greatest number of magnetic lines, thus producing the maximum E. M. F.

**The Simms-Bosch Spark-Advance.**—The spark may be advanced by a feather on the cam, set in a spiral groove cut on its spindle, so that when the spindle moved lengthwise the drop of the contact breaker may occur at an earlier moment, although maintaining the sparking point at the same maximum position of

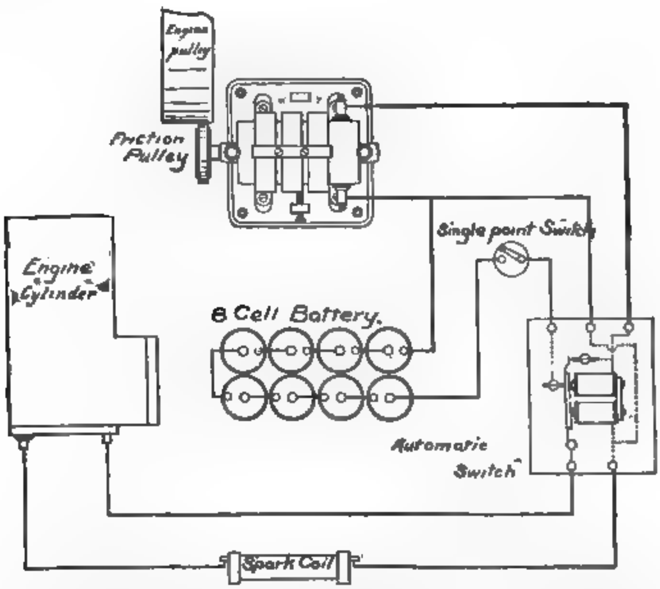



FIG. 175.—A Primary Spark Ignition Circuit, containing a magneto-generator, an 8-cell chemical battery, and an automatic cut-off or relay The chemical battery is used to supply the current for producing the spark until the magneto-generator has attained its required speed. At that point the current from the generator passing through the coil of the automatic switch is sufficiently strong to cause the magnets of the relay to attract their armature and cut the circuit of the chemical battery. This circuit may also be cut out at any time desired with the single point hand switch.

the oscillated sleeve. The positive terminal is on an insulated binding screw at the top of the armature, the path of the return current being through the metal of the engine cylinder to the base of the magneto.

**Driving Connections for Magneto-Generators.**—In general, the method adopted for driving the rotating portion of a magneto is to connect it direct to the fly-wheel of the engine, either by a

belt or a brushing roller bearing on a chamfered portion of the circumference. With this arrangement it has usually been found that a current sufficient to begin sparking may be produced by the act of turning over the fly-wheel to start the motor.

**The Primary Spark.**—The primary spark is so called because it is produced on a primary circuit, as distinguished from one occurring on a secondary circuit, or a circuit carrying a stepped-up current, induced in an induction coil, when a battery circuit is periodically made and broken, as will be subsequently explained. While it is possible to produce a small spark by simply breaking a battery circuit, it is necessary in order to have a spark of sufficient intensity and duration to introduce an effect of self-induction. This is done by passing the direct current—generally from a commutated magneto—through the winding of a long-wound magnetic or reactance coil.

**The Primary Coil.**—The spark coil used in this method of ignition consists of a long iron core wound with a considerable length of low-resistance copper wire, the length of the core and the number of turns of the insulated winding determining the efficiency. The current passing through the winding magnetizes the iron, and a self-induced current is generated, which is occasioned by and superposed on the battery current. As soon as the circuit is broken, the magnetic reactance tends to continue the flow of current, despite the gap, and occasions a spark of great heat and brilliancy. The spark occurs at the moment of breaking the circuit, not at the moment of making. With high speed engines a shorter core is used on the coil, a smaller magnetic lag being thus obtained.

**Typical Means for Producing a Primary Spark.**—There are two typical methods of producing a primary spark:

1. *By wiping contact*, in which one of the electrodes is constantly rotated, a spark occurring when the contact between the two is broken at a point suitably shaped on the rotating member. The wipe contact is unfamiliar on motor carriage engines.

2. *By breaking contact,* in which two metal terminal electrodes, normally in contact, are separated at the proper moment for the spark.

**Relative Advantages of Wipe and Break-Sparks.**—The advantages of the wiping contact are that the surfaces of the electrodes are constantly wiped clean of any impurities produced by the combustion of the fuel charge in the cylinder. It has, however, an even greater disadvantage involved in the enormous wear of the small points due to constant friction. The simpler make-

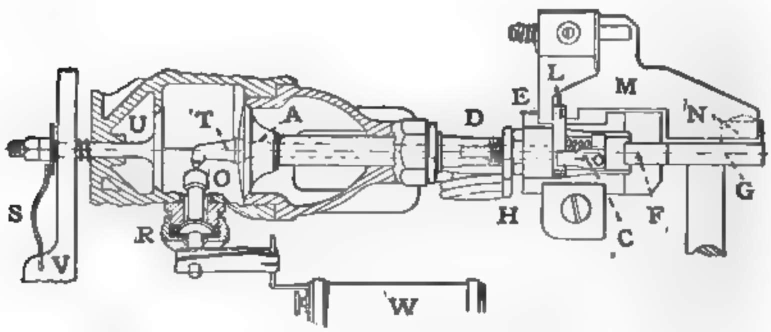



FIG. 176.—The Duryea Primary Spark Ignition Apparatus. A is the exhaust valve; D, the exhaust valve stem; T, the stem of the sparker hammer, journaled in the stem, D; E, the exhaust slide; F, roller at end of E; G, the rotating exhaust cam; H, exhaust valve spring J, a clamp fixed in position by a set screw; M, pivoted lift that trips the hammer, L, operated by roller, N, beside the exhaust cam, knocking the sparker, T, away from the insulated plug, O. U is the inlet valve; V, the throttle slide; S, spring controlling the opening of U; W, the spark coil; R, the metal union nut, clamping O in place.

and-break device, on the other hand, while producing quite as good a spark, permits no really reliable method of preventing the deposit of carbonized particles.

**Typical Break-Spark Igniters.**—The most widely famous primary ignition systems are those used on the early Mors carriage motors and the Simms & Bosch system, already noticed. Among the best known makes of American gasoline carriage motors using the primary spark may be mentioned the Duryea and Haynes-Apperson.

The Duryea make-and-break apparatus closely resembles the Mors. The current is carried to the engine by a bare wire attached to an insulated stem by a spring clip, which is caused by vibration to grip tighter, thus insuring a constant contact. Around the middle of this insulated stem is a flange, on both sides of which ordinary mica washers are placed. A metal union nut or cap, *R*, binds the mica washers and the stem to the base of the plug, *O*, which in turn screws into the cylinder wall, allowing the end of the plug to project inside. This end is tipped with a ring of nickel alloy, which resists both heat and corrosion better than other metals, and can be turned around when worn. The mica insulation is not exposed to soot, oil and burned gases, and keeps clean. Through the hollow stem of the exhaust valve is inserted a sparker stem having conical ground joints in the exhaust valve seat, and with bent point or arm nickel tipped and adapted to contact against the insulated nickel ring. The projecting outer end of this sparker stem is provided with a hammer spring and clamp, the latter being held by a set screw firmly on the stem. A flat lift raised by a roller on the exhaust cam raises the hammer and permits it to drop suddenly under the action of the spring, causing it to strike the clamp and knock the sparker point out of the engagement until the lift is again operated. The exhaust cam pushes the exhaust valve with the sparker parts out of the way, so that the lift may return to its original position, ready to repeat the operation. This mechanism is quite simple and is located on top of the motor in a most accessible position.

**Production of the Jump-Spark.**—With the jump-spark produced from a secondary circuit, there are no movements of the electrodes, the primary circuit being periodically broken by a positively operated circuit-breaker, which thus induces an intermittent current of varying intensity in the secondary. The electrodes are usually contained in a device known as a sparking-plug, in which they are insulated from one another, by the use of porcelain, mica or other suitable substance. The most common objection to the use of the jump-spark is found in the fact

that particles of carbon dust, produced by the combustion of the fuel charge, are deposited between the small sparking points, thus preventing the formation of a spark by filling up the gap across

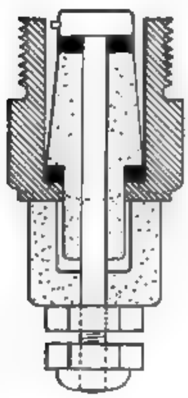


FIG. 177.

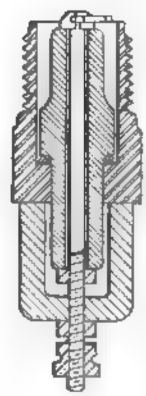


FIG. 178.

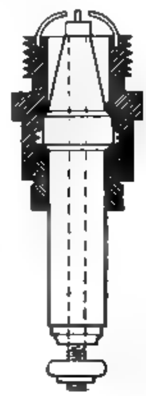


FIG. 179.

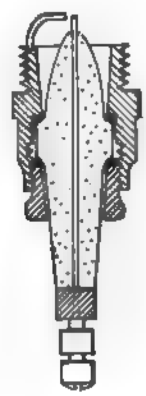


FIG. 180.

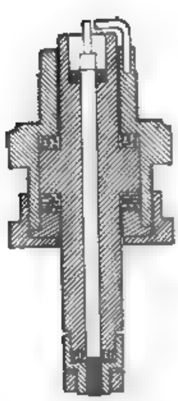


FIG. 181.

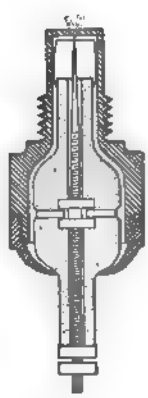


FIG. 182.

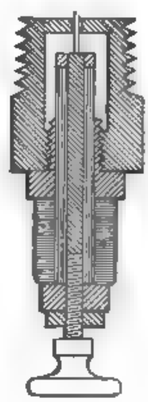


FIG. 183.

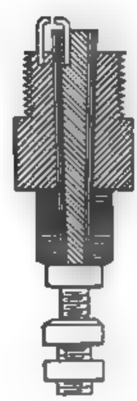


FIG. 184.

FIGS. 177-184.—Sections of Well-known Spark Plugs. The first six have porcelain insulation, the last two, mica.

which the current is obliged to leap in forming the spark; or collecting over the surface of the plug and short-circuiting the current.

**Construction of Jump-Spark Plugs.**—As shown in accompanying sectional cuts of typical jump-spark plugs, there are elements entering into the construction of all common forms of this device:

1. The ground electrode, consisting of a metal cup, threaded on its outside circumference for screwing into the metal of the cylinder wall, to which one side of the high-tension circuit is usually grounded.

2. An insulating barrel of mica or porcelain firmly retained within the metal cup.

3. The opposite electrode of the circuit, consisting of a thin rod of metal contained within the insulating barrel.

4. Two sparking points, one attached to each electrode, and separated by a gap of about $\frac{1}{32}$ inch, so that the high-tension current may leap across between the points, forming a spark.

In many modern spark plugs there is an annular clearance between the insulating barrel and the inside of the cup-electrode. This is provided for the purpose of reducing the danger of short-circuiting by leaving a larger space between the two electrodes than will ordinarily be filled with carbonized residua. According to some designers, it also insures a vortex for the gases, circulating in the combustion chamber, under the impulse of the piston strokes, thus expelling a large part of the deposits.

**Short-Circuiting of Plugs.**—The principal occasions for short-circuiting of a plug are the excessive deposit of carbonized residua between the electrodes, or between the sparking points, as just explained, and breaking down of the insulation. The latter accident occurs with both mica and porcelain insulators:

1. In mica insulation, by the deterioration under heat of the cement used to join the several layers of the mica, particularly when oil or other substances are forced between them.

2. In porcelain-insulated plugs, when the porcelain cracks under heat, affording opportunity for the collection of oil, etc.

**Spark-Plug Insulation: Porcelain.**—Porcelain is well suited for spark-plug insulation, since it possesses a very high resistance both to heat and to the electric current. In fact, a high quality of porcelain should not break down with either the heat or the electrical tension encountered in gas-engine operation. That porcelains are broken under such conditions is due to uneven heating of the insulating tube or to some unexpected violence. The brittleness of porcelain is nearly the worst objection to its use. Lower qualities of porcelain are, of course, much more easily broken, and thereby produce short-circuiting under ordi-

FIG. 185. Double Spark Plug used on the Cadillac Engine. Unlike other plugs, the secondary circuit is carried by visible leads, and is not grounded at any point. Superior sparking qualities are claimed, and, as seems evident, fouling is a more remote danger.

nary conditions of temperature and electrical tension. Many plugs using porcelain insulation have the porcelain in two or more parts, so as to avoid the troubles arising from uneven temperatures. Heat is liable to break a single long porcelain.

**Spark-Plug Insulation: Mica.**—Mica, a substance possessing an electrical resistance of 84,000,000,000,000 ohms per cubic centimeter, is an ideal insulator, except for the fact that it frequently contains impurities that reduce its dielectric efficiency, and also because, owing to its laminated structure, oil and gas may be forced by the pressure of compression between the sheets composing the insulating sheath, thus, in time, producing short-circuiting of the current. Most mica-insulated plugs having the

inner spindle sheathed with concentric coats of mica have also a cap at the end of the sheath to protect it and to ensure the attachment of the spindle. One manufacturer, whose plug is shown among the sections, adopts the plan of tapering both the electrode spindle and the mica sheath around it, thus, as is claimed, producing a perfectly gas-tight joint, and, instead of allowing gas to be forced between the laminæ, providing for an increasing tightness of contact as the metal of the spindle expands with heat.

On mica insulation one authority remarks:

"Mica cores, built up of thin disks of sheet mica, even if carefully selected, are seldom free from iron, and the sheet mica cannot be so closely united as to entirely prevent a deposit of fine particles of carbon being pressed between the layers by the force of the explosions, thus rendering the insulation imperfect. This causes misfiring, and as the offending plug is to all appearances perfect, it often occasions the operator much annoyance.

"These remarks also apply to other substances, such as lava or artificial stone, which, being porous, are imperfect insulators."

**Secondary Sparking Circuits.**—In order to obtain a secondary current with the use of a chemical battery or direct current mechanical generator, it is necessary to interrupt the primary circuit at timed intervals. There are two methods by which this is accomplished:

1. By the use of a snap cam that once in every revolution brings together the terminals of the circuit.

2. By the use of a wipe-contact interrupter, or "commutator," and a magnetic trembler at one pole of the coil-core.

Only a very rudimentary knowledge of electrical apparatus is required to make it evident that snap cam and trembler cannot be advantageously used in the same circuit. The two varieties of apparatus are very well shown by the two typical circuits, the De Dion and Benz. Both of them also illustrate the prevailing method of grounding the negative lead of the secondary circuit to the metal of the engine. The general principles are explained with single cylinders, but multiple cylinder arrangements are shown later.

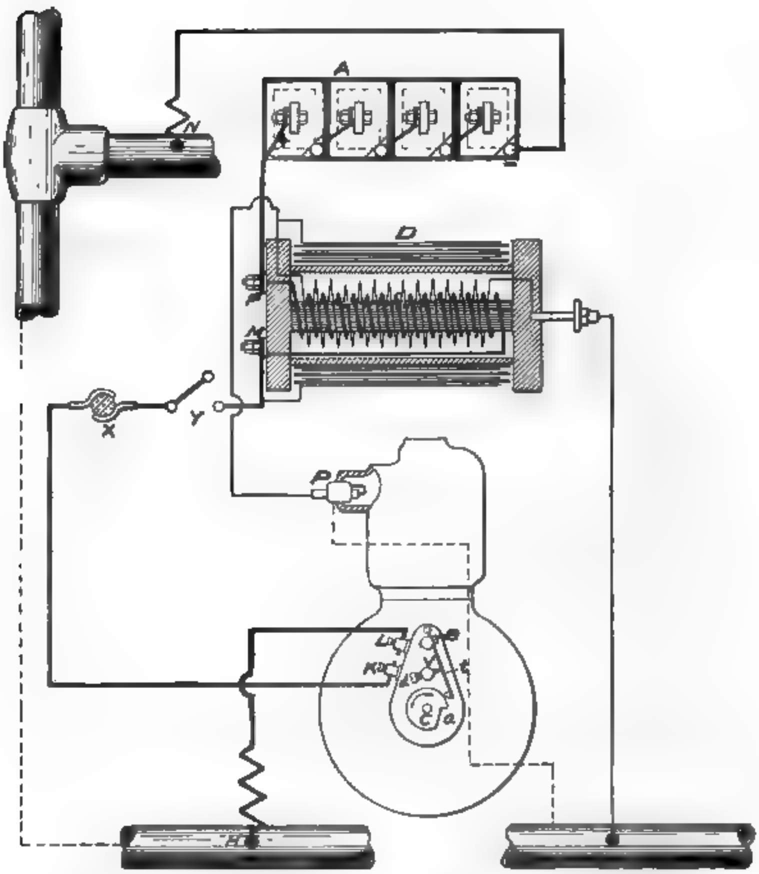
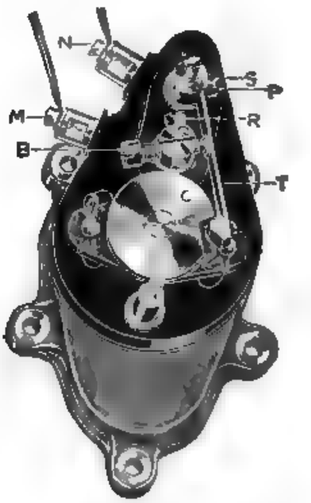



FIG. 186.—Diagram of the De Dion Jump-Spark Ignition Circuit A is a battery of four cells, one pole of which is connected, as shown, to the tubular frame of the carriage at the point, N, the circuit being thus completed through the steel frame work to binding post, L, on the circuit breaker; thus, the circuit is made by the contact of the trembler, T, with the point of the screw, D, on the post, V, through binding post, K to M, thus through the primary winding of the induction coil and to the opposite pole of the battery. The secondary circuit joined by one pole of the condenser, D, is connected to one end of the sparking plug, P, the other, being grounded to the frame, completes the circuit by the metallic contacts with the body of the motor, as indicated by the dotted line

**The De Dion & Bouton Jump-Spark Circuit.**—The general plan of connections for the De Dion jump-spark circuit is shown

in an accompanying diagram. Here, as may be seen, the current produced by a chemical battery is passed through the primary winding of the induction coil, the circuit being periodically broken by a vibrating trembler and snap cam, the details of which are given in another figure. The positive pole of the battery is connected to the primary winding of the induction coil, the opposite



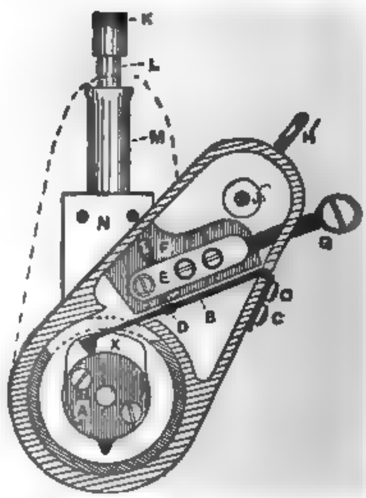
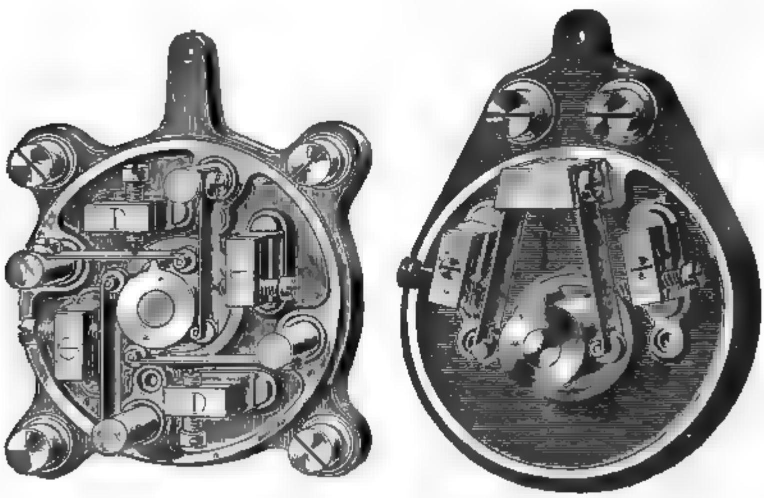




FIG. 187.—The De Dion and Bouton Single Cylinder Circuit Breaker. B, platinum-ended screw; C, notched cam; M, terminal in contact with B and Q; N, wire terminal in contact with P, S and T; P, stud supporting the trembler; Q, split projecting stud supporting the platinum tipped screw, B; R, screw to make Q grip B; K, screw fastening trembler, T, to base, P; T, the trembler spring.

FIG. 188.—Contact Breaker of the Minerva Single-Cylinder Tricycle. A, rotating cap on end of secondary shaft, carrying point to left trembler, B; X, cap to lift valve stem; C, C, screws connecting trembler spring to frame; D, stud of platinum making contact with tip of E; F, mica sheet; G, brass screw holding one end of the circuit wire; K, exhaust valve lift; L, stem sliding inside of tube, M, secured to plate, N; H, ring for holding wire screwed at G; J, pivot for rod moving contact breaker through arc from position shown to that indicated by dotted outlines.

terminal of which is connected to the lower of the two binding screws attached to the vulcanite base of the contact breaker. The negative pole is grounded to the frame of the carriage and thence to the metal of the motor cylinder, the circuit being completed by a wire connecting with the upper binding post on the contact-breaker.

*The operation of the contact-breaker* is obvious. It consists of a positively operated cam on the two-to-one shaft, of round contour except for an irregular sector-shaped notch in its circumference, which allows the point of the trembler, *T*, to drop when the notch meets it in the rotation of the cam, thus making contact from the terminal, *B*, and the upper binding post on the base of the apparatus, with the negative pole of the battery, and the screw, *d*, which is connected through the lower binding post with



FIGS. 189 and 190 —Contact Breakers for Two and Four-Cylinder Engines of the general type resembling that shown in the last figure. As may be seen, the springs are brought into contact with the anvils representing the terminals of the circuit, as the projecting point on the sleeve rotates so as to engage each roller in turn. Such apparatus are used in circuits having no tremblers on the coils.

the positive pole of the battery, as already explained. By this means, the circuit being periodically broken, a powerful high-tension current is induced in the secondary winding of the induction coil, one terminal of which is connected with the insulated portion of the sparking plug, the other with the metal of the cylinder, the spark being produced between the terminal contacts of the plug at every interruption. By this arrangement of the circuit the electrical potential of the secondary circuit, and therefore of the grounded point of the sparking plug, are reduced to the lowest

value, the negative terminal of the battery affording a constant dead ground at a much lower potential than may even be found in the metal base of the machine as a whole.

On closing the primary circuit through the contact spring, as already described, the current in the primary winding of the induction coil rises rapidly to its full value against the opposing self-induced current generated in the coil, and establishing a powerful magnetic field, whose lines of force intersect the plane of the convolutions in the secondary circuit, creates therein, during the brief period when the battery current is flowing, a constantly increasing difference of electrical pressure between the grounded secondary terminal and the opposed extremity of the same winding. The difference of electrical pressure, resulting from the increasing density of the magnetic field, is not great enough, however, to cause a spark discharge between the points of the plug, owing to the fact that the range of change in the density of the magnetic field is retarded by the self-induction of the primary circuit opposing the rapid flow of the battery current. A condenser is therefore used, one pole of which is connected to the primary terminal, wired to the lower binding post of the contact-breaker and thus to the screw, *D*, already mentioned, the other being connected to the grounded terminal of the secondary circuit. By this means the magnetic field produced in the primary winding of the coil is almost instantly destroyed whenever the battery circuit is broken. Thus, it is possible to obtain a high-speed rate in alternately making and breaking the primary circuit, while at the same time maintaining a secondary current of sufficient potential to produce a powerful spark without interference from the self-induced current produced in the primary winding of the coil. The action of the condenser is virtually "a heaping up of electrical pressure at the end of the wire of the primary circuit, to which it is attached." This, discharging through the only available outlet, sweeps back through the primary coil and instantly demagnetizes the core, owing to the fact that its flow is in the reverse direction to that of the original self-induced current. This effect is produced with great rapidity, and is a potent factor

in rendering the De Dion system one of the simplest by which a high-tension current may be generated for ignition purposes. Among the objections to the system may be mentioned the fact that a large primary current is required in proportion to the useful work accomplished, which contributes to the end of speedily exhausting the battery.

**The Benz Jump-Spark Circuit.**—Instead of the notched cam and trembler spring of the De Dion circuit, the Benz uses a leaf spring, carrying a contact button at its free point, and bearing against the circumference of a rotating insulated disc, which through a small arc carries a brass plate electrically connected to its spindle. This spindle forms one terminal of the induction coil primary. The spring bearing upon the periphery of the rotating disc is connected direct to the negative pole of the battery. By this means, whenever the brass plate on the disc comes in contact with the button carried at the extremity of the spring, the primary circuit is formed.

*The induction coil* used with this ignition system is of the usual construction, except that it has a magnetically operated contact-breaker, which serves to break the primary circuit as soon as the core has acquired its full magnetic properties. The current, emerging from the positive pole of the battery, moves along wire, *A*, to binding-post, $A^1$, and thence to the screw, *B*, which is normally in contact with spring, *C*, of the contact breaker. Moving through the spring, it emerges on wire, *D*, thence through the primary winding of the induction coil to binding-post, $E^1$, and wire, *E*, which is in electrical contact with the spindle, *F*, of the rotating disc, *G*. The circuit is closed, as already stated, whenever the brass arc, *H*, on the periphery of the disc is brought into contact with the button, *K*, carried on the spring, *L*. The point of ignition may be timed by modifying the relative positions of the contact piece, *H*, and the button, *K*, this act being accomplished by loosening the adjustment screw and turning the disc, *G*, on the spindle, *F*, to the required point. The metal sleeve, *M*, in contact with the spindle, *F*, maintains the electrical contact be-

tween *H* and *F*, and thus with the wire, *E*, no matter what may be the degree at which the contact, *H*, is shifted. The spindle, *F*, being a secondary shaft, rotates so long as the engine is in motion, thus making the primary circuit once in every two revolutions of the fly-wheel.

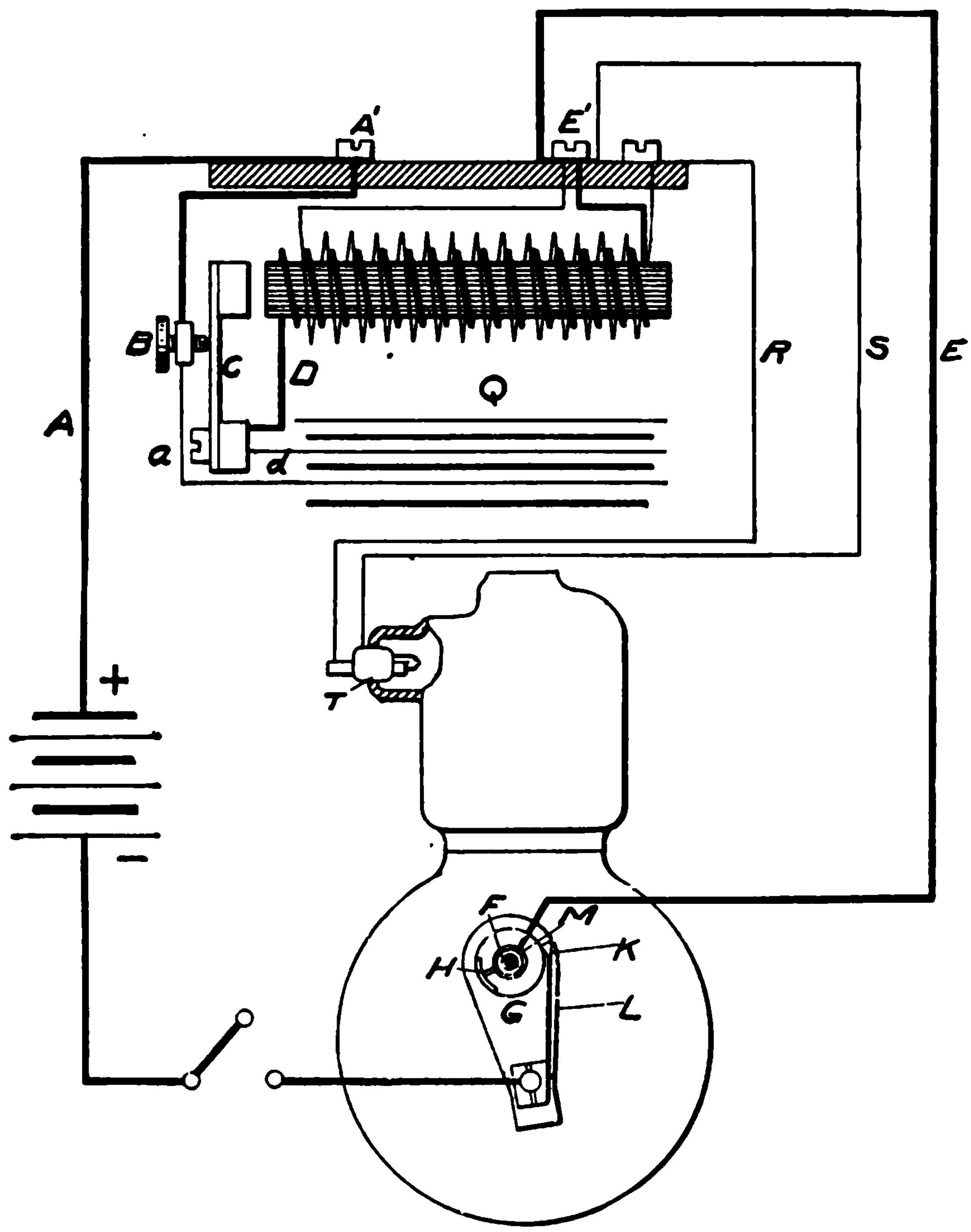



FIG. 191.—The Benz Jump-Spark Circuit. Both primary and secondary circuits are carried by visible leads, no part of either being grounded to the frame. The primary circuit is traced through wire, A, to binding post, A′ on the coil, to contact, B, of the trembler, C, thence through C and D to the primary winding of the coil; with a shunt on wires, *a* and *d*, through the condenser, Q. The primary winding emerges from binding post, E′, passing over lead wire, E, to sleeve, M, of the rotary cam, G. The sleeve, M, is in electrical contact with the metallic section, H, on the cam, being turned on the spindle, F, so as to periodically make contact with the head, K, of the trembler spring, L. The secondary circuit passes through lead wires, R and S, to the two terminals of the plug, T.

The two terminals, *B* and *C*, of the wires, *A* and *D*, are connected as shown by the wires, *a* and *d*, with the condenser, *Q*, the object being, as with the De Dion system, "to suppress the

spark discharge of the primary self-induced current, which otherwise would take place on the break of circuit, and to increase the rate of demagnetization of the core."

As may be readily understood, the primary circuit has scarcely been made before the iron head of the contact breaker, carried on the spring, *C*, is attracted to the core of the induction coil, thus momentarily stopping the flow of current. Its vibrations, however, are of great rapidity, averaging at least four complete breaks during the brief period in which the brass piece, *H*, on disc, *G*, and the button, *K*, on spring, *L*, are in contact. The re-

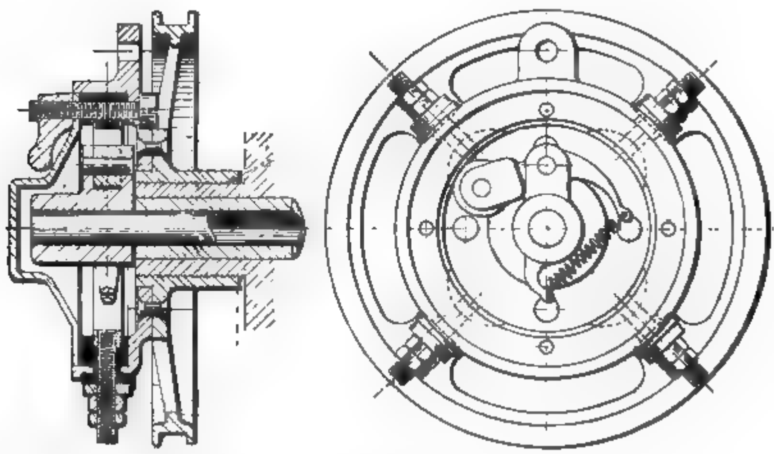
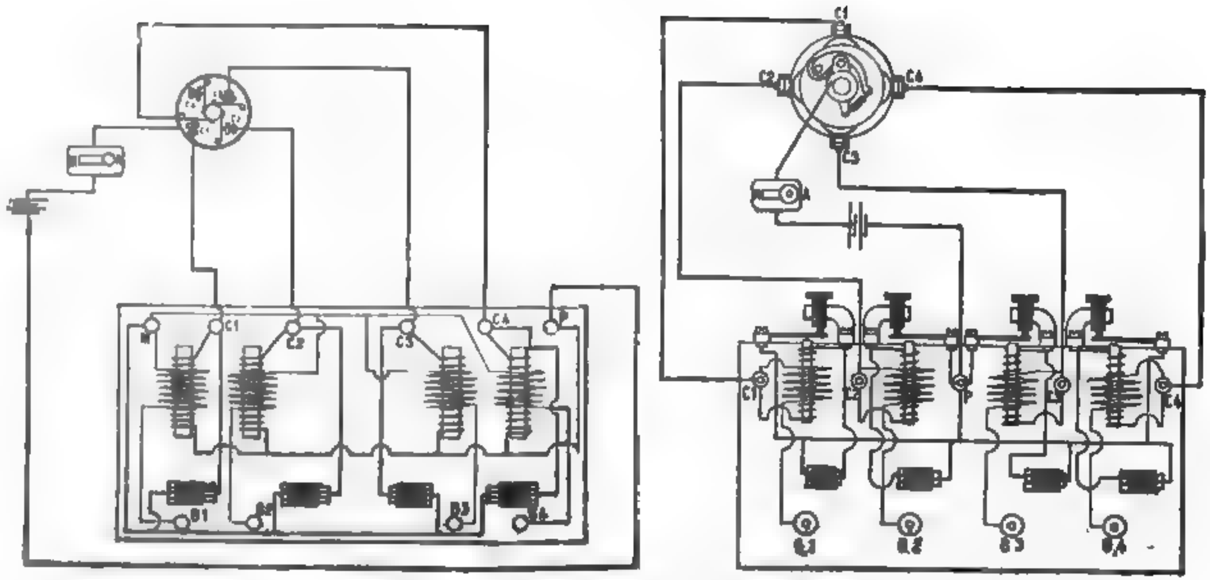


**Fig. 192.**—Type of French Wipe-Contact Circuit Interrupter used on Circuits having Magnetic Tremblers on the Coils. As shown, the roller comes into contact with the arc-shaped plates representing terminals of each of the four coil and plug circuits, making each of them in succession.

sult of these rapid fluctuations of the magnetic field is a continuous stream of hot, flaming sparks between the points of the plug, during the period in which the primary circuit is made, the number of impulses of the secondary current on the wires, *R* and *S*, to the two terminals of the sparking plug, *T*, being greatly increased.

**Timing the Spark.**—With neither of the systems as described is there any provision, except adjusting the cam, for advancing




FIGS. 193 and 194.—Diagrams of Four-Cylinder Sparking Circuits, the first using a drop cam contact breaker without magnetic tremblers on the coils; the second, a wipe-contact interrupter with tremblers. In these figures, A and M are the off and on positions of the switch; $C^1$, $C^2$, $C^3$, $C^4$, the primary terminals of the coils; P, the opposite pole of the batery; M, the point of grounding the secondaries; $B^1$, $B^2$, $B^3$, $B^4$, the plugs. Details of circuits as in the typical circuits already described.

or retarding the time of the spark—which is to say, making the closure of the primary circuit at a point shortly before or shortly after the completion of the compression stroke. By advancing the spark a longer period of expansion, consequently a greater economy of effective power, is obtained: by retarding it the expansion is shortened, and the power effect is not as great. The best efficiency is obtained when the piston moves outward under full power impulse from the very start, which is possible when the gas mixture is in a state of complete ignition.

The control of the spark could be constantly in the driver's hand with such motors as have been just described, if the cam or the commutator were set on a sleeve, arranged, as in the Simms system, to be shifted around through part of a revolution, thus making the spark occur at an earlier or a later moment, or if the base holding the binding screws and contact spring were arranged to move through a short arc around the secondary shaft. Such an arrrangement has actually been applied on a single cylinder bicycle motor, with which a snap cam contact breaker is used.

With multiple cylinder engines very similar devices are used for periodically making the circuit. With many of the best makes of carriage the coil is furnished with a magnetic trembler and the primary circuit is made and broken by a rotating wipe contact commutator. As shown in accompanying figures, the rotating member may be either an insulated disc with a single conducting contact, as in the Benz jump-spark circuit, or a contact piece bearing on an internal insulated track with conducting surfaces corresponding to the number of cylinders to the fired and to the disposition of their cranks in degrees. With such devices the spark may be timed, either by turning the frame through part of a revolution, or by turning the sleeve carrying the rotating member. Precisely similar apparatus are made to operate with snap cams, as shown in the figures. Several carriage motors have the spark timed by automatic governor. With others it is done solely by the action of the driver.

**The High-Tension Magneto.**—Within a few years a new variety of ignition apparatus has been introduced in the high-

tension magneto. Briefly described, it consists, typically, of a magneto in which the current, generated in the low resistance winding of a rotating, oscillating or stationary armature, is transformed by a high resistance winding, usually on the same armature, and distributed to the cylinders from a rotating-contact "commutator." The machine is, therefore, a generator, induction coil and distributor combined in one working whole. The leading adantages of the high-tension magneto are:

1. The spark occurs at the points of highest tension or when the polarity of the armature is about to be reversed.

2. The spark may be timed, advanced or retarded, so as to bring it always at the points of highest tension, as cannot be done with the ordinary induction coil. The igniting current is literally fed direct from the armature winding. Any variation in the time of ignition—an advance or retarding of the spark—involves simply altering the relative position of the armature spindle, so that the points of highest tension are reached earlier or later, as the case may be.

**The Synchronous Drive.**—As may be readily understood, the high-tension magneto must be driven "synchronously," which is to say, at a speed in ratio to that of the engine—generally at one-half engine speed for a four-cylinder engine—in order that the spark may always occur at precisely the proper point in the rotation of the armature. The drive may be by toothed wheel gear or chain and sprocket. The friction gear drive or belt and pulley are alike objectionable, from the fact that no slipping or variation are permissible. While some recent forms of high-tension magneto are advertised to operate asynchronously, the common types of this instrument are so made that the spark shall occur in the first cylinder at precisely the moment the magneto armature is at a certain point in its rotation. If, therefore, this condition is not strictly observed, the spark will be of defective intensity, and the control of the engine will be greatly complicated.

**Types of High-Tension Magneto.**—There are several types of high-tension magneto, all combining, however, the essential features of high-tension current wipe-contact distributor and spark-timing by altering the relative rotative positions of engine-shaft and generator-spindle. Among the best known types are the Simms-Bosch, the Lacoste and the Eisemann.

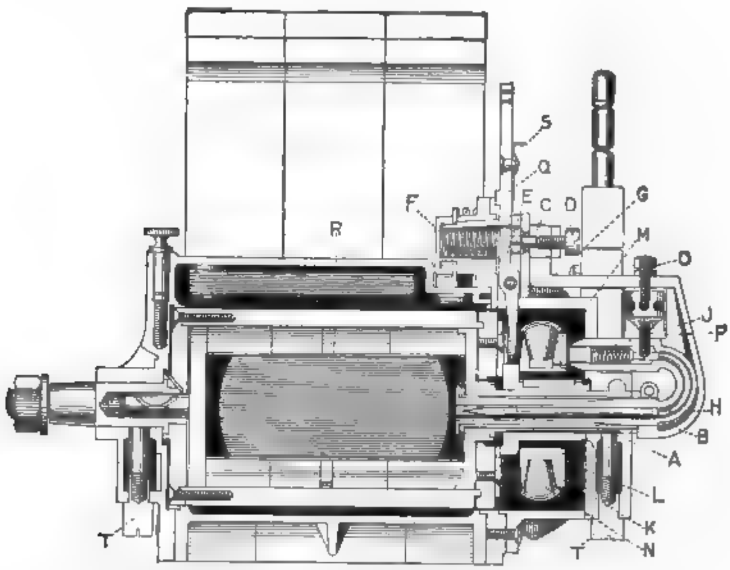



FIG. 193.—Section through the Simms-Bosch High-tension Magneto. A, armature shaft; B, curved arm carrying high tension lead; C, lug supporting screw, D, adjusting contact breaker, E, against spring, F; G, revolving sleeve carrying face cams; H, high tension lead wire; J, carbon brush of distributor disc; K, insulated ring; L, rotating drum of distributor; M and N, distributor brushes; O and P, safety spark gap; Q, swiveled lever for retarding or advancing the spark time; R, condenser; T, T, spring-pushed wick oilers for armature spindle.

**The Simms-Bosch High-Tension *Magneto.***—The Simms-Bosch high-tension magneto for jump-spark ignition circuit resembles the low-tension magneto of the same name in combining a stationary H-shaped armature and a rotating or oscillating sleeve, as already described. The armature, however, is double-wound, around the cross-line of the *H*, with a low-tension and a high-tension coil, which thus lie parallel to the axis of the sleeve spindle. The low-tension coil is grounded to the armature frame

at one terminal and to an insulated contact in the frame of the machine at the other. Its circuit is broken four times in each revolution of the rotating sleeve by a make-and-break contact lever, which is successively raised by four insulated face-cams on the end-plate of the sleeve. At the moment of breaking the primary circuit, the secondary current is at its maximum tension, its circuit being made through one of the contacts of the rotary distributor, through the spark plug wired to that contact and back again to the frame of the magnets. A condenser is included on a shunt for the same reason as in any other form of high-tension circuit

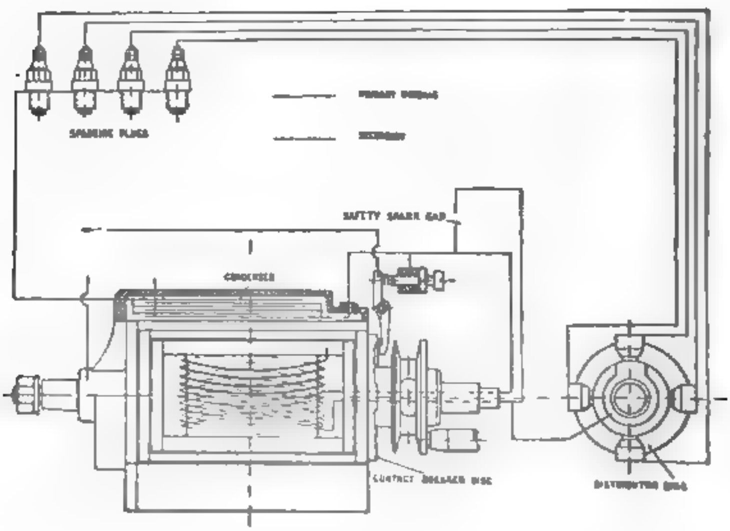


FIG. 186.—Circuit Diagram showing the Simms-Bosch High-tension Magneto wired up to spark a four-cylinder engine.

**The Simms-Bosch Timing Gear.**—Since, as has already been explained, the act of sparking in the cylinders is accomplished on the breaking of the primary circuit, when the contact lever is raised by one of the face-cams of the sleeve, the readiest means for advancing or retarding the spark is to be found in moving the contact lever through part of a revolution, either backward or forward, so as to hasten or delay its engagement by the next

face-cam. The axis of the rotation is the same as that of the armature sleeve, but the arm carrying the contact-lever, also the rotary wipe contact of the high-tension distributor, may be moved forward or backward through so small an arc, that the electrical conditions are unaltered. The only effect, therefore, is to make the spark occur a few degrees earlier or later.

**The Simms-Bosch Current Distribution.**—The secondary current is led from the armature winding by a wire, encased in a curved tube, which emerges from the spindle of the armature. Thence, through a carbon brush, bearing upon a flat brass ring, on the front of the distributor, it passes to the contact-segment; being conveyed to each spark plug in turn through the four brushes of the distributor. All these details may be readily learned by reference to the diagram of circuits.

**The Lacoste High-Tension Magneto.**—Like the machine just described, the Lacoste magneto has both primary and secondary coils wound upon the cross piece of the H-shaped armature. Unlike it, however, the armature rotates on its axis between the pole-pieces of the magneto; no sleeve whatever being interposed. The primary circuit is grounded to the frame of the machine at one terminal, and to insulated brass collector ring, around the circumference of the armature, on the other. This circuit is broken four times in each revolution of the armature by a four-pointed snap cam, which raises a spring out of normal contact with a terminal anvil; thus, also, interrupting the secondary current at its point of highest tension, and giving occasion for a powerful discharge, through the secondary contact, to the spark plug.

**The High-Tension Circuit.**—The current from the secondary coil is led through an insulated conductor within the armature spindle, being conducted thence by a metallic lead to the centre of the distributor spindle. The distributor disk carries a contact leaf, which, in rotating, wipes each of the plug terminals in turn.

The other side of the secondary circuit is grounded and a condenser is included on a shunt, acting to produce the sparking discharge on the interruption of the current, as in other jump-spark circuits. Except for the difference in distributor mechanism, the outside circuit wiring of the Lacoste magneto is similar to that of the Simms-Bosch.

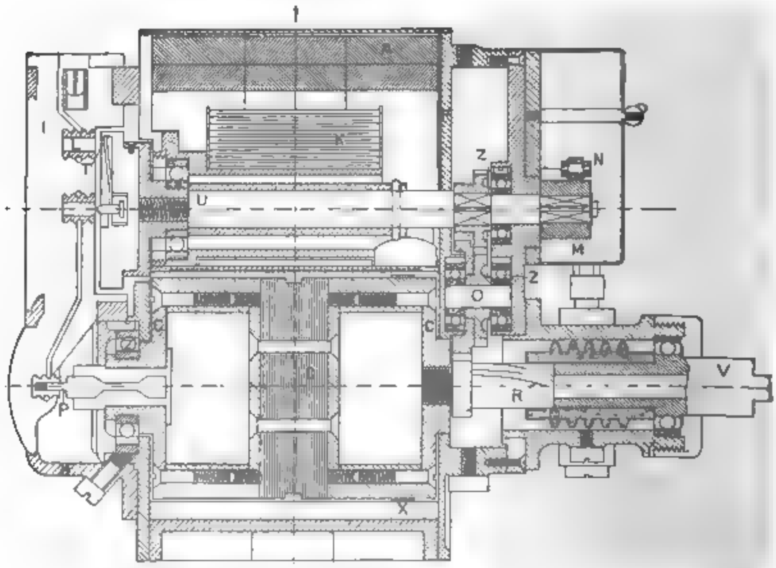



FIG. 197.—Section through the Lacoste High-tension Magneto: A, permanent magnets; C, C, non-magnetic end plates of armature; D, laminated core of armature; H, aluminum case; I, vulcanite spring and conductor case; K, condenser; M, contact breaker cam shaft; N, roller bearing on M; O, gear wheel driven from armature shaft, P; Q, timing sleeve; R, helical groove on P; T, high-tension distributor spring; U, secondary or distributor shaft; V, shaft driven by engine; X, wipe ring; Z, Z, ball bearings.

**The Lacoste Timing Apparatus.**—The advance and retard of the spark in the Lacoste magneto is accomplished by varying the relative rotary positions of the armature and engine shafts. In other words, the armature is thrown backward or forward, as it rotates, so that the points of highest tension will be reached later or earlier than normally, as the case may be. Briefly described, the timing apparatus operates, as follows: The driving shaft, connected by spur gear or sprocket to the engine, and

the armature spindle are set end to end, separate, although having their axes in one line. The driving shaft has a spiral groove, cut on its circumference from right to left, and the armature shaft, a spiral groove, cut from left to right. A sleeve is slid over both shafts, with feathers arranged to fit into the grooves. This sleeve furnishes the means for making the two shafts continuous, hence, of transmitting the rotation from the one to the other. It also enables the timing of the spark in the manner already suggested. A number of parallel flanges around its circumference fit into a toothed sector, which, when turned through part of a rotation on its axis, moves the sleeve inward

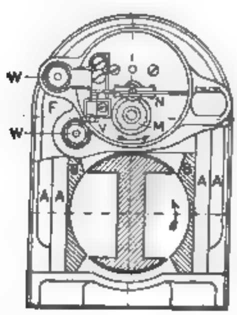


Fig. 198.

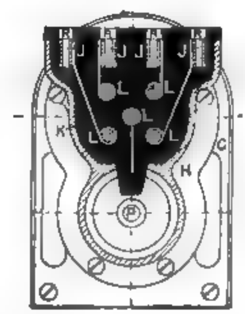


Fig. 198a.

Fig. 198.—Front View of the Lacoste High-tension Magneto, showing operative parts. A, A, A, A, permanent magnets; B, B, pole pieces; F, part of face plate of machine; M, contact-breaker disc with four peripheral cams, shown just before the correct position for breaking contact by lifting roller, N, and its spring from contact at V; W and W, binding posts.

Fig. 198a.—Rear View of the Lacoste High-tension Magneto, showing distributor mechanism. G, end plate; H, distributor case; K, vulcanite bed of distributor; J, J, J, J, high-tension terminals; L, L, L, L, L, wipe contacts and spindle of distributor, T (see Fig. 197); R, R, R, R, plug holes for lead wires.

or outward. The effects produced by the lengthwise movements of the sleeve is a turning backward of the armature spindle, when the sleeve moves toward the machine, and a turning forward, when it moves away from it. In the first case, therefore, a point on the armature reaches a given point in relation to the pole pieces later than normal; and, in the second case, it reaches the same point earlier than normal. Thus, the point of highest tension of the secondary current is delayed or hastened, and the spark is retarded or advanced as a consequence. When the

armature spindle is thus twisted back of the rotation, or ahead of it, the primary circuit-breaking apparatus is similarly affected by the motion transmitted to the train of reducing gears by which it is driven from the armature shaft.

**The Eisemann High-Tension Magneto.**—The Eisemann magneto differs from the others so far noticed in the fact that it generates a low-tension current, which is periodically interrupted by a rotating circuit breaker, and stepped up by an induction coil of the usual description, separate from the machine

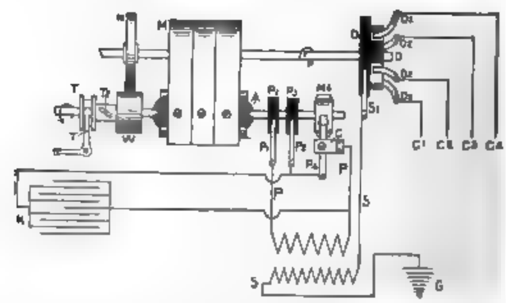



FIG. 199.—Circuit Diagram of the Eisema n High-tension Magneto. A, armature; C, primary c'rcuit breaker; $C_1$, $C_2$, $C_3$, $C_4$, high-tension leads to cylinders; D, high-tension distributor disc; $D_1$, $D_2$, $D_3$, $D_4$, distribu or wipe contacts; G, primary ground on metal of engine; K, condenser; M, permanent magnets; N, gear on distributor shaft; P, P, primary circuit of induction coil; $P_1$, $P_2$, wipe contacts on distributor rings of primary circuit; S, S, secondary circuit; T, bell crank for timing; $T_1$, spool in which bell crank works; $T_2$, slotted sleeve on driven shaft; W, gear on driven shaft.

itself. It differs from the ordinary magneto igniter, however, in the fact that the high-tension current, induced in the secondary winding of the induction coil, is distributed to the spark plugs in the engine cylinders, from a rotary distributor, driven direct from the armature shaft, and timed with its advance or retardation.

The low-tension current, generated in the rotating armature, is taken off by a carbon wipe contact, and passed through a cam-actuated contact breaker to the primary winding of the coil. The high-tension current is led from the coil to a rotating brass ring on secondary shaft, driven direct from the magneto armature. This brass ring carries a vulcanite fibre disc, with a single con-

ducting segment, through which the current is commutated to four leaf-spring contacts bearing against the vulcanite face.

The position of the brass ring and the vulcanite disk, carrying the conducting segment, may be altered by the alteration of rotative position of the armature shaft, in a manner similar to that noted with the Lacoste magneto. The armature shaft is driven through a sleeve, within which a helical groove is cut. A pin set into the armature shaft works in this groove, and, when the sleeve is slid forward or back, furnishes the means for twisting the shaft backward or forward.

**Merits of Break and Jump Sparks.**—The two varieties of spark used in igniting gas engines are, at the present time, more evenly divided than formerly, in the favor of builders and users of motor vehicles. Constantly, however, the necessity increases for a form of ignition apparatus suited to the requirements of high-speed engines. A small or weak spark will occasion slow ignition, consequently, also waste of fuel and loss of power; while a large and hot spark effectively explodes the charge, giving full power, and greatly reducing all losses.

The jump spark was doubtless adopted in the belief, that a high-tension current could more efficiently ignite the charge, than one produced by make and break on a low-tension circuit. It has proved, however, by no means as satisfactory as required under all conditions. Frequently the spark-gap would become fouled, probably owing, in considerable measure, to weak sparks, produced at points other than that of maximum tension. Some years since, the outside, or extra, spark-gap was advocated as a sufficient preventer and cure for such troubles. It proved of less importance than many were led to suppose. Latterly, the high-tension magneto has come, presenting the advantage of timing the spark to occur at the precise moment of highest tension in the secondary circuit.

**The Production of Electric Sparks.**—The primary spark, as already explained, is produced, when, on the interruption of the circuit, the magnetic reactance, due to the self-induced current

in the coil, tends to continue the flow of current, despite the break. The result is a spark discharge, generally of great size and brilliancy. The secondary spark is produced by the oscillatory discharge of the condenser shunted around the coil, and increases in intensity in direct ratio as the impedance and inductance in the circuit increase in relation to the ohmic resistance. Principally on this account a magneto or dynamo is preferable, as a source of current, to a battery of cells, and, beyond a certain very definite point, the difference between the two varieties of electric source is fundamental.

**The Size of Electric Sparks.**—Regarding the size of the two kinds of spark, hence their ability to explode, rather than progressively ignite the charge in cylinder, Charles E. Duryea makes the following statements:

"An easy comparison of the two sparks is made as follows: Pass a strip of paper between the points of the jump spark plug and the paper will be perforated by the sparks, leaving a line of minute holes. To get the actual size of the spark in the cylinder, in the presence of the compressed charge, the points should be separated ¼in. or more, for it is well known that the compressed air is an insulator, and that engines which frequently miss on full charges will fire regularly when the charge is throttled, thus proving that there is a larger and a better spark when there is no compression.

"Connect one wire of the make-and-break system to a piece of sheet metal on which is placed a sheet of thin paper, preferably held 1/32in. above the surface of the metal. Connect the other wire to a common pin and push the point through the paper, after which pull the pin away quickly. A large spark will follow, burning a hole through the paper frequently ⅛in. in diameter. Compare the area of this hole with the area of a minute perforation made by the jump spark, remembering that the make-and-break spark is also longer, and it will be seen that the volume and heat of the make-and-break spark is much larger, on which account it will fire a less perfect mixture, and thus secure more reliable action and greater economy."

**The Duryea Exploder.**—With a view to realizing the full power of the primary spark, Duryea designed the form of exploder shown in an accompanying figure. Briefly described,

it is a magnetic coil, wound upon a perforated core, and enclosed within an iron shell. A hinged armature is set above the pole of the magnet, and to it is attached a metal sparking pin, which passes through the hole in the coil core, to within a short distance of the metal sparking point within the cylinder. In the figure, an exploder is shown connected to one brush contact of a triple rotating commutator with wiring indicated to two other exploders and to the magneto generator.

From the generator, the current flows, when connected by the commutator, through binding-post, 1, to the coil of the magnet,

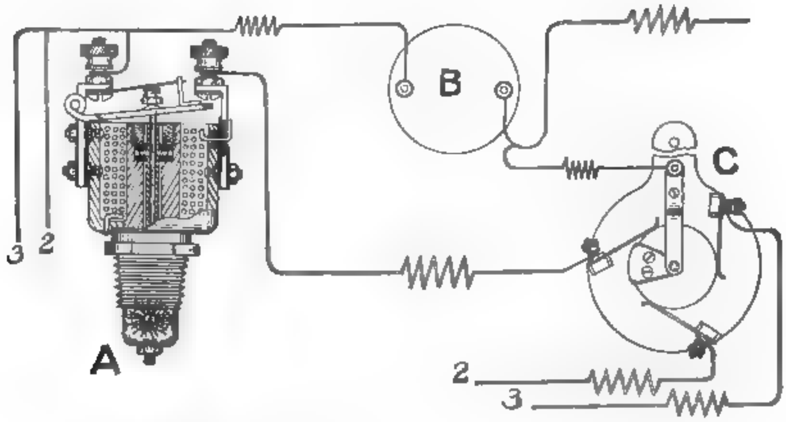



FIG. 200.—Three-Cylinder Circuit Diagram of the Duryea Exploder. A, exploder plug showing interior; B, retardation coil; C, contact breaker; 2 and 3, leads to second and third cylinder exploder plugs.

finally grounding on the shell of the magnet and returning, by the way of the engine and the ground wire of the generator, to complete the circuit. The magnet instantly attracts the armature and forces the reciprocating spark pin firmly into contact with the adjustable sparking point within the cylinder, thus closing the sparker circuit. This permits a flow of current through the coil, thence to binding-post, 2, and through the armature and sparking pin to the engine and ground wire of the generator. The resistance of the magnet winding is so great that but little current flows through it, and this forces almost the entire output of the generator through the coil, thoroughly saturating it. When

the magnet circuit is broken at the commutator, the armature is released and flies back quickly, under the action of its spring, striking the head of the sparking pin, (still held in contact by a light spiral spring) and knocking it out of contact with very great velocity. The superior results of the hammer-blow make-and-break are much improved by the fact that the moving part is very light and susceptible of extremely rapid movement. The entire strength of the current is available to close the contact, and, since magnetic pull increases inversely as the square of the distance, the contact is always firm and sure. Once in contact, a very small current suffices to hold the armature, because of the short distance and the very great pull exerted by the magnet, when once closed. This permits nearly all the current to saturate the coil, even while the magnet winding is in circuit. The breaking of the magnet circuit throws all the current through the coil, charging it to the fullest as the magnet discharges, and, in addition, throwing into the coil the intense discharge impulse of the magnetic circuit, actually compounding the effect.

The spark does not occur until the magnet circuit is broken at the commutator, and this magnet circuit has no function but to close and break the sparking circuit. This insures that the spark coil is saturated as fully as the source of current will permit, instead of making a spark as soon as the magnet is strong enough to work the armature and before the coil has time to saturate.

# CHAPTER TWENTY-SIX.

## BALANCING GASOLINE ENGINES.

**Balancing Gasoline Engines.**—An important item in the operative efficiency of any type of engine is balance. This involves some mechanical means for rendering all movements perfectly even and for neutralizing thrusts and vibration. Balance is particularly necessary in an internal-combustion engine of any type, since, with a power effort applied only at stated intervals, instead of continually, as in a steam engine, there is a far greater likelihood of irregularity at some point in the cycle. The most probable results of unbalanced movement in a gas engine will be:

1. Vibration, with attendant wear on the supports of the engine.

2. Wear on the moving parts, as between the piston and cylinder bore and at the bearings of the shafts. This must sooner or later result in the disablement of the engine.

3. Loss of efficiency, on account of the creation of numerous stresses which absorb power.

**Causes of Unbalanced Motion.**—The problem of properly balancing an internal-combustion engine has always been serious, and considerable ingenuity has been exercised in the effort to achieve a perfect solution. The effort to transform reciprocating into rotary motion must inevitably be attended by strains and vibration, which, when proper adjustments are absent, result in wear on the bearings and deformation of the cylinder bore. In a single-cylinder gas engine the vibrations resulting from inertia of the moving parts, moving under varying stress through the several stages of the cycle, are liable to be excessive. It is necessary, therefore, to provide some means for compensating this irregularity, so that, as far as possible, the active energies may be equalized.

**Balancing a Single-Cylinder Engine.**—Very few single-cylinder gas engines have been constructed with more than an approximate balance. This is true because the only available

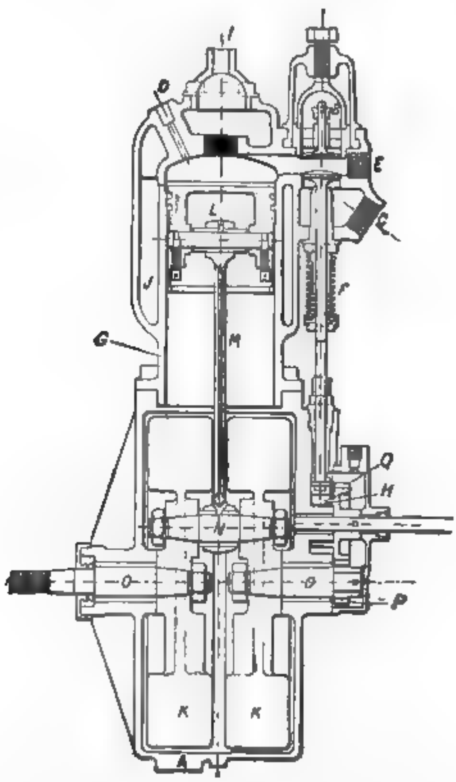



FIG. 201.—Section of the De Dion and Bouton Single-Cylinder Water-Jacketed Carriage Engine. Parts are as follows. A, crank case formed by two cylindrical pieces bolted together; B, the inlet valve for the fuel mixture from the carburetter; C, the exhaust valve, held closed by a helical spring, F, and opened by the cam, H; D, the opening for the compression tap; E, the threaded hole for the sparking plug; F, the spring on the exhaust valve rod; G, the cylinder; I, the port of exit for the jacket water from jacket, J, the inlet being at a point near the base of the jacket; K and K are the flywheels, or crank discs, which are joined together as shown, by the crank pin, N; M is the connecting rod; N is the crank pin; O and O are the crank shafts, that on the right carrying the pinion, P, that on the left being threaded for connection to the driving gear; P is a pinion on the crank shaft meshing with gear, Q.

method is to set balance weights opposite the crank pin; and to make balance weights balance is a very delicate problem. In

general, the proper weight to be used for good balance must be equal to the weight of the moving parts to which it is opposed. According to the generally accepted theory, the weights to be

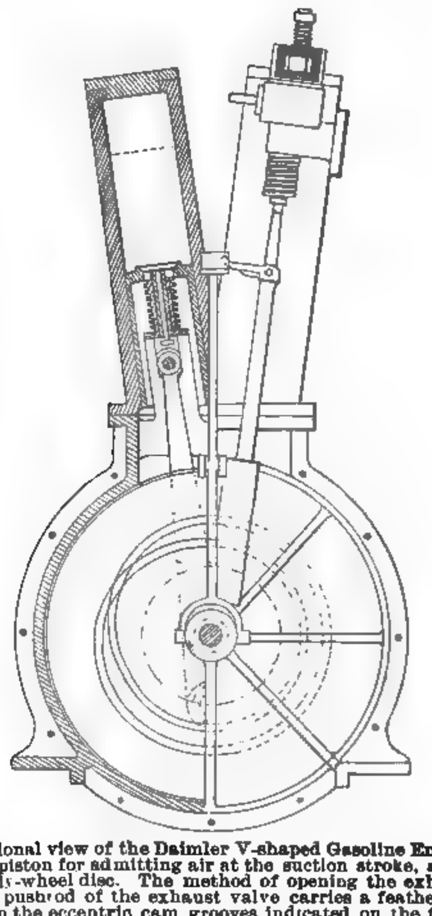


FIG. 202. -Part sectional view of the Daimler V-shaped Gasoline Engine, showing the air valve in the piston for admitting air at the suction stroke, and eccentric cam grooves on the fly-wheel disc. The method of opening the exhaust valve is also indicated. The pushrod of the exhaust valve carries a feather at its lower end, which travels on the eccentric cam grooves indicated on the face of the piston. Under impulse from the centrifugal governor, at high speed, the feather follows an approximately circular path, thus preventing the push rod from lifting and pushing the valve rod, to open the valve.

considered are those of the crank and crank pin, together with a certain portion of the weight of the connecting rod. In determining the correct portion of the weight to be used, the method

usually followed is to set the piston end of the rod on a knife-edge support and to hang the opposite or crank end to a spring-scale balance. This weight, which will naturally be smaller than that of the connecting rod wholly supported by the balance, may be taken as the greatest weight that is mechanically significant.

**Arrangement of the Cranks.**—It may be safely said, that for success in balancing a single-cylinder vehicle engine, De Dion & Bouton, of France, stand almost alone. In other carriages than theirs, especially those of American manufacture, vibration was at one time an almost inevitable feature. This trouble early led to the construction of motors with several cylinders. Daimler's V-shaped double-cylinder engine was nearly the first meritorious attempt to balance the moving parts of two cylinders. It consisted of two cylinders inclined from the vertical, so as to form an angle of about 30 degrees with the connecting rods working on a common crank. Later on, Daimler engines were made with two vertical parallel cylinders, with cranks at 180 degrees. This arrangement soon proved ineffective to prevent vibration, and, as a consequence, the common crank was restored, both pistons making their out-strokes and in-strokes simultaneously.

**Proportions of the Bore and Stroke.**—Another element of design that undoubtedly contributes largely to the end of attaining balanced operation is the proper proportioning of the parts. The superior balance of the De Dion single-cylinder engine is to be attributed to the fact that the stroke is short, in proportion to the diameter of the cylinder, quite as much as to the adjustment of moving weights. Very many carriage engines have the stroke length and diameter of bore approximately equal, while in few of them is the stroke very much the longer.

**Double-Piston Cylinders.**—In addition to adjustment of moving weights, several engines have been designed to balance the reaction produced by explosion of the charge by the use of two pistons in one cylinder, set face to face, so that both are forced outward by the power impulse. In such engines, of which the

Gobron-Brillie is a type, approximate freedom from vibration is accompanied by two other advantages—greater velocity of expansion, with consequently greater speed, and immunity from leakage, due to joints and gaskets in the cylinder.

**The De Dion Two-Cylinder Engine.**—One of the most notable attempts to neutralize vibration in a four-cycle engine is the De Dion balanced double cylinder. In this engine the two cylinders make their out-strokes and in-strokes contemporaneously, as in other double-cylinder engines. Balance is secured, however,

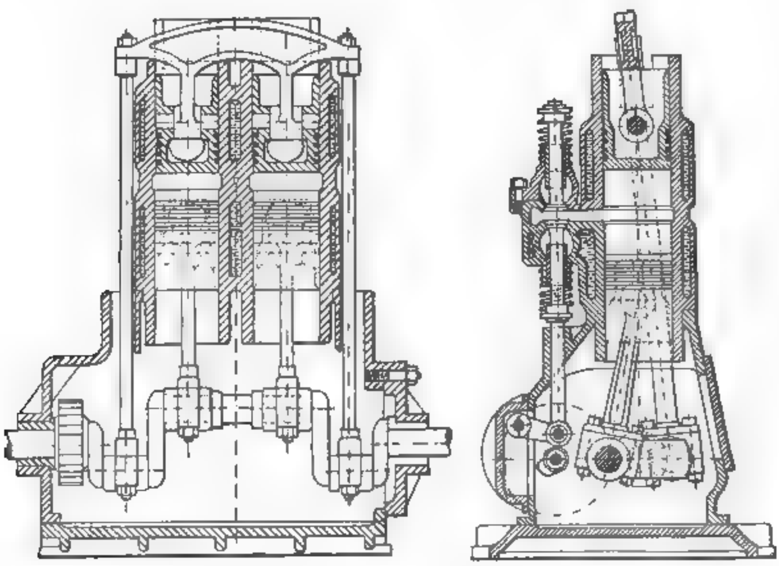


FIG. 203.—The Gobron-Brillie Two-Cylinder, Four-piston Balanced Engine.

by the use of a third cylinder, in which slides a piston, equal in weight with its connecting rod to the weights of the moving parts in the other two. This third cylinder performs none of the functions of power production, its sole purpose being balance of motion. The crank of the third piston is set at 180 degrees to the other two. According to published statements, excellent results were attained in practice with this engine.

**Single and Multiple-Cylinder Engines.**—As may be readily seen, the double-opposed-cylinder engine, with cranks at 180 degrees, originally designed by Daimler, and greatly developed in America, is only another means of achieving the approximate balance made possible by the use of one crank with two parallel cylinders. Experience seems to justify the statement that the horizontal opposed-cylinder engine is the best available form for achieving good balance with two cylinders. It was formerly the prevailing form of engine for American automobiles of average power and is now the only form of two-cylinder four-cycle engine in general use.

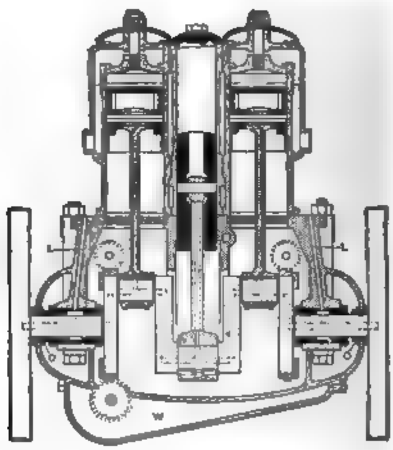


FIG. 204.—The De Dion & Bouton Two-cylinder, Three-piston Balanced Engine.

Owing principally to the fact that the pistons of the two cylinders work upon opposite sides of the crank-shaft, it is possible to balance the moving parts without the use of balance weights. With proper design and workmanship, therefore, easy running seems to be very well assured. The builders of the famous Haynes-Apperson opposed two-cylinder engine claimed for it so high an immunity from vibration that an electrical generator could be driven, direct-connected to its main shaft, and supply current for incandescent lamps with no preceptible variation in voltage.

**The Three-Cylinder Engine.**—The three-cylinder engine, having its cranks set at 120° has been used on several motor vehicles, and has proven itself an improvement on either the single or double cylinder, in point of easily-achieved balance of the working parts. The single-cylinder engine has a power stroke in each two revolutions of the fly-wheel, and the double-cylinder, in each revolution. In the three-cylinder engine, however, a power stroke begins at each 240° of rotation, or three power strokes to a complete cycle of two revolutions. As shown in the accompanying folder diagram of the cranks and cycles of multiple-cylinder engines, two-thirds of the compression stroke in each cylinder of a three cylinder engine takes place under

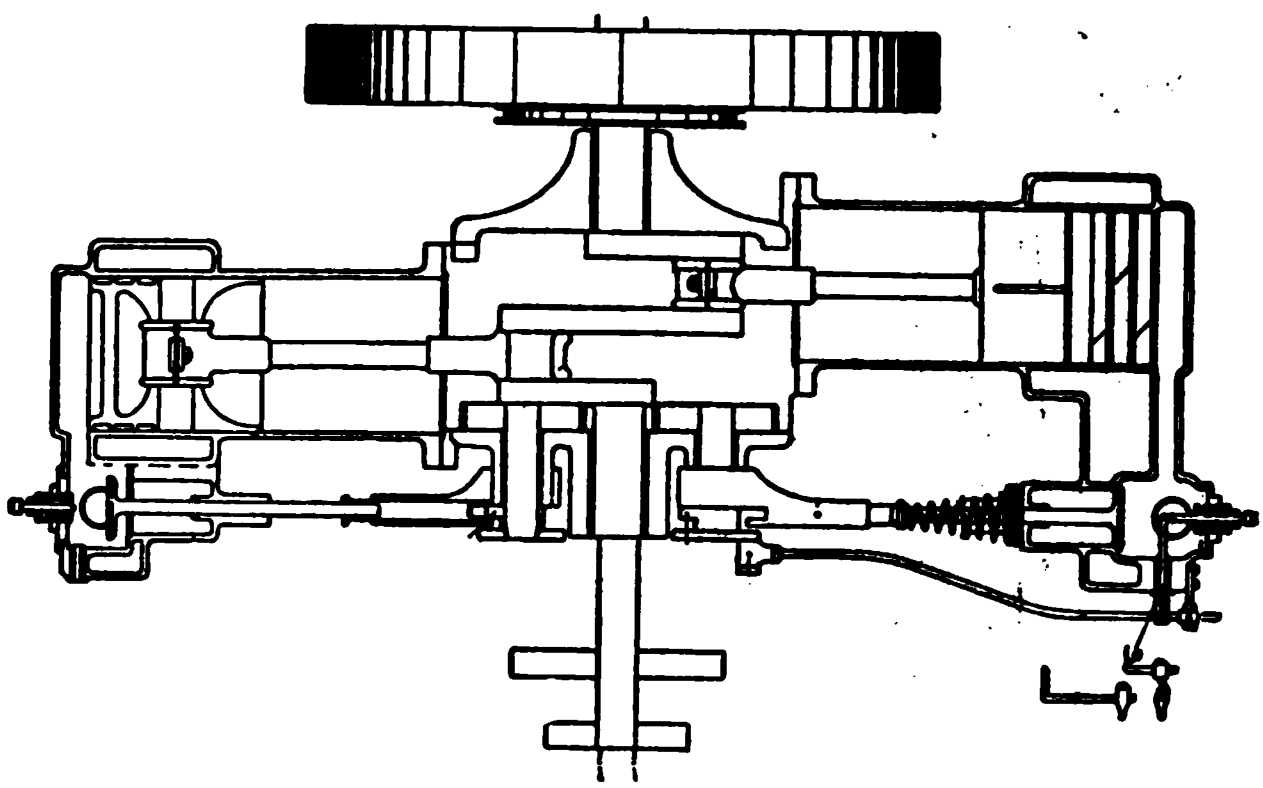


FIG. 205.—Sectional Diagram of the Haynes-Apperson Double-Opposed Cylinder Motor, showing valve arrangements and details of primary ignition device.

power impulse on the crank. This is a valuable contribution to balanced operation; since, in single and double cylinder engines, the strain put upon the fly-wheel of compressing the charge to the high point used in many modern engines, must be disturbing to perfectly even running, unless the fly-wheel be very heavy and extremely well calculated for its duty. Another advantage, claimed for the three-cylinder engine, is that none of the several stages of the cycle in one of the three cylinders is precisely contemporaneous with any other stage in another cylinder. The effect of successive high-resistance (compression

and suction), power-impulse (expansion) and low resistance (exhaust) are distributed or neutralized; thus rendering more even the rotative stress on the crank-shaft, and relieving the fly-wheel of a considerable percentage of its compensating duty. Whether or not these explanations perfectly explain, experience proves the superior balance of the three-cylinder engine, as used by Duryea and several other designers.

**Multiple-Cylinder Engines.**—The advent of the modern high-powered motor carriage involved the introduction of the

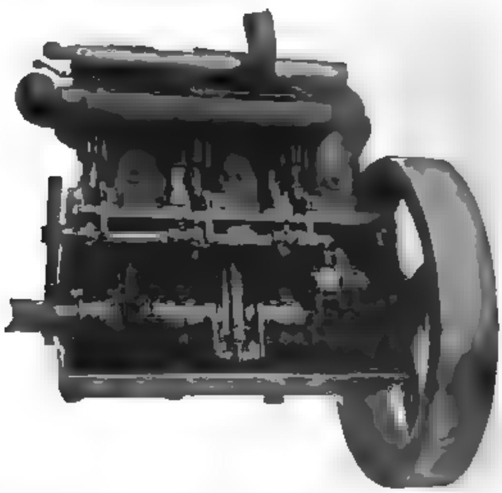


FIG. 206.—The Duryea Three-Cylinder Gasoline Vehicle Engine, with half the crank case sheathing removed, showing cranks, crank shaft, cam shaft, and working parts. The three cylinders have common supply and exhaust tubes; the charge is controlled by a single throttling link, shown at the top, and the igniting circuit has three bridges for the three cylinders. Cranks, as indicated, are at 120 degs.

multiple-cylinder engine, with four, and, latterly, with six cylinders. The reason for this change may be found in several important considerations:

1. The necessity of using larger, consequently heavier, cylinders to produce the increased power.

2. The difficulty of cooling large cylinders on high-speed engines.

3. The superior balance attained by increasing the number of the cylinders, and rendering the power-effect, as nearly as possible constant.

4. The liability to vibration in a gas engine decreases as the square of the number of cylinders; giving a four-cylinder engine 16 times less vibration than a one-cylinder, and a six-cylinder, 36 times less.

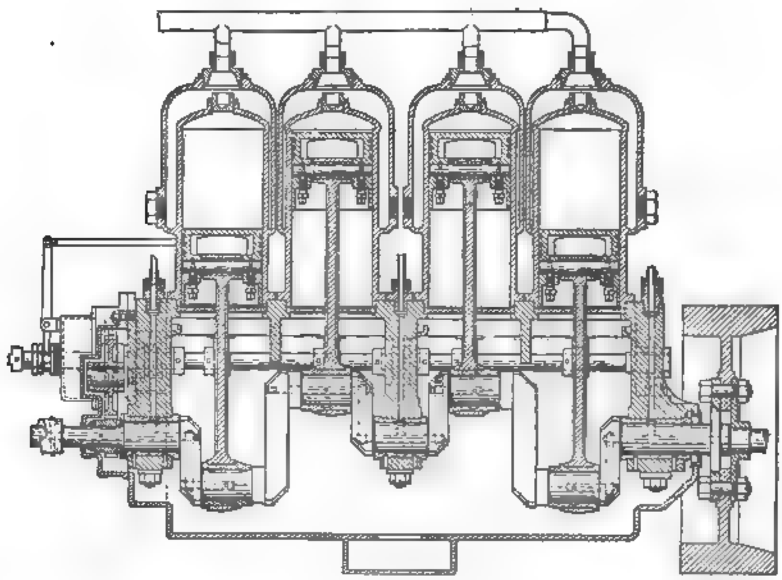


**FIG. 207.—A Typical Four-cylinder Engine (Pierce), showing position of cranks and working parts, including secondary shafts.**

**The Four-Cylinder Engine.**—As shown on Faurote's crank and cycle diagram, the four-cylinder engine enables the realization of a nearly-constant power impulse. In other words, a power stroke is occurring in some one of the four cylinders throughout the entire two revolutions of the cycle. Since, however the exhaust opens before the ends of the power stroke, thus rapidly reducing the power-pressure on the piston head, the power effort is neither constant nor uniform. This implies that the balance of the four-cylinder engine is not perfect, particularly

at low speeds, when fluctuations in the power effect have relatively greater opportunty to interrupt the steady pull on the shaft. This is shown in a later paragraph.

**The Six-Cylinder Engine.**—Faurote's diagram also shows the six-cylinder engine and its relative advantages. Here, taking the circle as a complete cycle of two revolutions, or 720°, it may be seen that the value of the power-efforts on the crank shaft is practically constant. As indicated in the diagram, the order of firing in the cylinders is 1st, 5th, 3d, 6th, 2d, 4th. Taking the outermost of the six concentric circles as representing the cycle of the first cylinder, it may be seen that the suction stroke begins at the meridian, or 1°, and, extending through 180°, is followed by the compression stroke. The firing stroke begins at 360°,

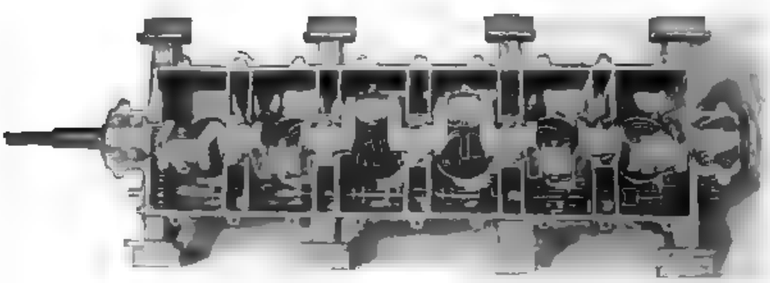


FIG. 208.—Crankshaft of the Olds Six-Cylinder Engine, showing positions of the cranks.

and is completed at 540°. The exhaust opening, being set to occur at about 500°, is slightly preceded by the maximum in the fifth cylinder, which, as may be seen, occurs at 480°. The maximum in the first cylinder, occurring at 360°, involves that the first third of the power stroke in that cylinder is contemporaneous with the last third of the power stroke in the fourth cylinder. The second third of each power stroke is, therefore, the only portion that is not contemporaneous with some part of the power stroke in some other of the cylinders. This arrangement achieves a fairly approximate balance of pressure conditions, high with low, and low with high, throughout the entire cycle for six cylinders.

**Multiple-Cylinder Performance.**—A suggestive series of experiments on the balance and operation of four and six-cylinder engines is recorded in the following quotation from the well-known English automobilist, S. F. Edge, in a recent issue of *Motor Trader.* Beginning with a comparison of cylinders required to produce a given horse-power efficiency, say 40 horsepower, he estimates in the following manner:

Single cylinder diameter, 10 in.; total force of explosion on piston head, 28,282 lbs.

Double-cylinder diameter, about 6 in.; total force of explosion on piston head, 14,141 lbs.

Triple-cylinder diameter, 5⅝ in.; total force of explosion on piston head, 9,427 lbs.

Four-cylinder diameter, about 5 in.; total force of explosion on piston head, 7,070 lbs.

Six-cylinder diameter, 4 in.; total force of explosion on piston head, 4,713 lbs.

On the basis of these figures, Mr. Edge concludes, as follows:

"I think at the present time the six-cylinder may be taken as ideal. * * * It gives absolutely smooth running, owing to the continuous turning motion, and, at the same time, enormously reduces the cost of up-keep, owing to this regular torque, both on tires and on mechanical parts.

"In order that the steadiness of torque or turning effort in a six-cylinder engine may be fully appreciated, the diagrams given have been constructed from actual tests.

"The first consideration to be taken into account is, of course, the variation of pressure in the cylinder. For the purpose of discovering what actually takes place, a standard 40 horse-power six-cylinder Napier engine was put under test, and a large number of observations made with manograph indicator and pressure recorder. As a mean of all these readings, the indicator diagram [shown in Fig. 209] has been constructed.

"The vertical line is graduated to give pressures in pounds per square inch. From the figure it will be noticed that the compression is carried to about 75 lb. per square inch. The ignition takes place considerably before the end of this stroke, and the pressure rises very rapidly to nearly 450 lb. per square inch. The enormity of this pressure can be better appreciated, when given in total pressure on the piston. The bore of the

cylinder is 4in., the area of the piston 12.56 square inches, and, therefore, the total pressure on each piston is roughly 2 tons.

"The diagram also clearly shows the fall of pressure during the working stroke, and the slight rise and fall above and below the atmospheric pressure during exhaust and suction strokes.

"At the beginning of the suction stroke, for instance, the piston is being pulled along at an ever-increasing rate while the crank travels through approximately 90 degrees. Then, until the end of the stroke the piston tends to keep on moving, and has to be retarded and brought to rest by the crankshaft. In other words, the inertia of the piston and parts moving with it is retarding the crank during the first half of each stroke, and urging it on during the latter half.

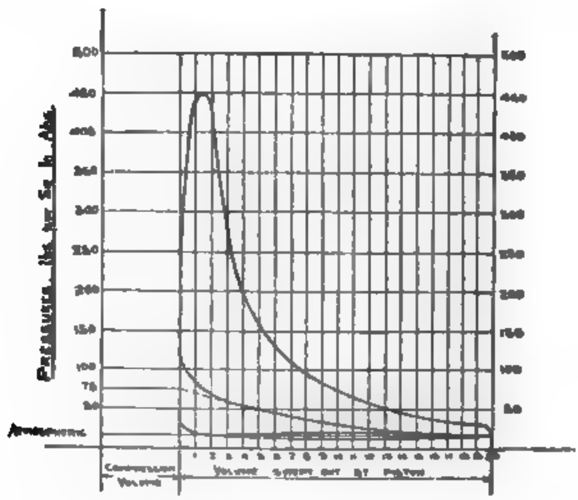


FIG. 209.—Edge's Average Diagram for Gasoline Engine Performances.

"The pressure in the cylinder and the force necessary to accelerate the piston have both been taken into account in the torque diagram for a single-cylinder motor. The turning effort is given in inch-pounds. For example, at point A, 400 inch-lbs. represent a pressure of 200 lbs. on the crank pin, tangential to the crank arm, and acting at a two-inch radius.

"The thick horizontal line represents the average turning-effort during the four strokes, which constitute the cycle. It also shows the effort of the inertia of the piston in giving negative and positive turning efforts at the beginning and end of each stroke. At the end of the compression

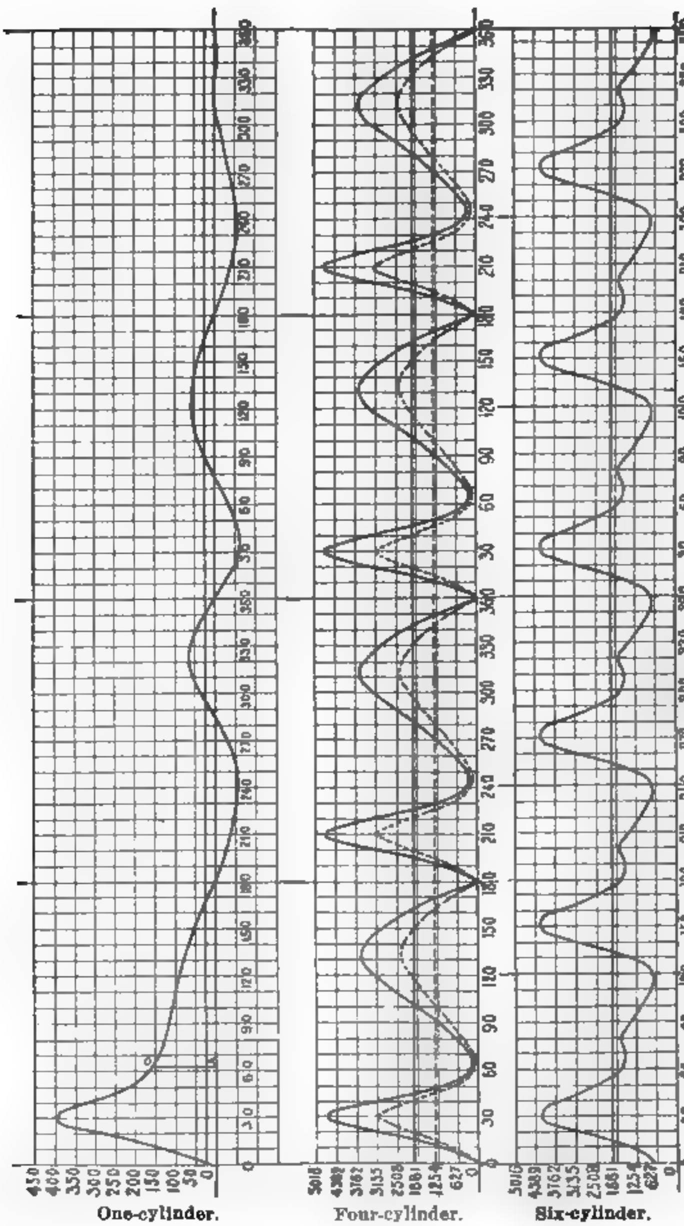



FIG. 210.—Edge's Torque Diagrams for one-cylinder, four-cylinder and six-cylinder automobile engines.

stroke, instead of getting a large negative turning effort, on account of the increased pressure in the cylinder, it will be seen that the torque has only a small negative value. This shows that the inertia of the piston coming to rest at the top of the stroke is nearly sufficient to compress the charge; also, when the crank is on the dead centres, there is no turning effort. It is from this diagram with its large variations that we must start and endeavor to obtain a constant torque.

"The dotted line in the four-cylinder figure is found by superimposing four of these diagrams, corresponding to four cylinders with crank at 180 degrees.

"It is not fair to compare the diagrams for four and six cylinders, for, the cylinders being all the same size, the six-cylinder engine will be giving one and a half times the power of the four, and therefore each vertical height of the dotted figure has been increased one and a half times to the full line, corresponding to larger pistons to equalize the powers of the two engines.

"The most important point to be noticed is that, with six cylinders, there is always a positive turning effort of at least 700 inch lbs. on the crank shaft, and that at no point of the cycle does it approach zero. With four cylinders and cranks at 180 degrees, there must of necessity be four points in the cycle, viz., when the cranks are on the dead centres, at which there can be no turning effort.

"The four-cylinder diagram shows also four other points, at which the torque has only a very small positive value, namely, less than 200 inch lb. This is accounted for by the retarding force of the pistons when being accelerated, after the effect of the explosion has passed. Had this diagram been constructed for any other pistons than the extremely light ones used in the Napier engines, it is extremely probable that at this point the torque would have a considerable negative value. The next rise in the torque is due to the forward pressure of the pistons when nearing the end of the stroke.

"A comparison of the two diagrams will be far more convincing than anything that can be written about them. The total inch-lb. pressures are given for convenience."

**Position and Timing of the Valves.**—Another matter logically related to the principles governing the balance of a four-cycle engine is the proper timing of the valves. As must be evident on reflection, the valves must open and close precisely at the proper moment, otherwise uneven working and waste of power

are inevitable. The timing of the valves is well explained by Fay L. Faurote in the following passage, quoted here by his courtesy:

"The points of opening and closing of valves are designated in two ways: either in terms of degrees around the fly-wheel, or as distance moved by the piston in the cylinder. As it is much easier, after the motor has been assembled, to determine the position of the piston from marks on the fly-

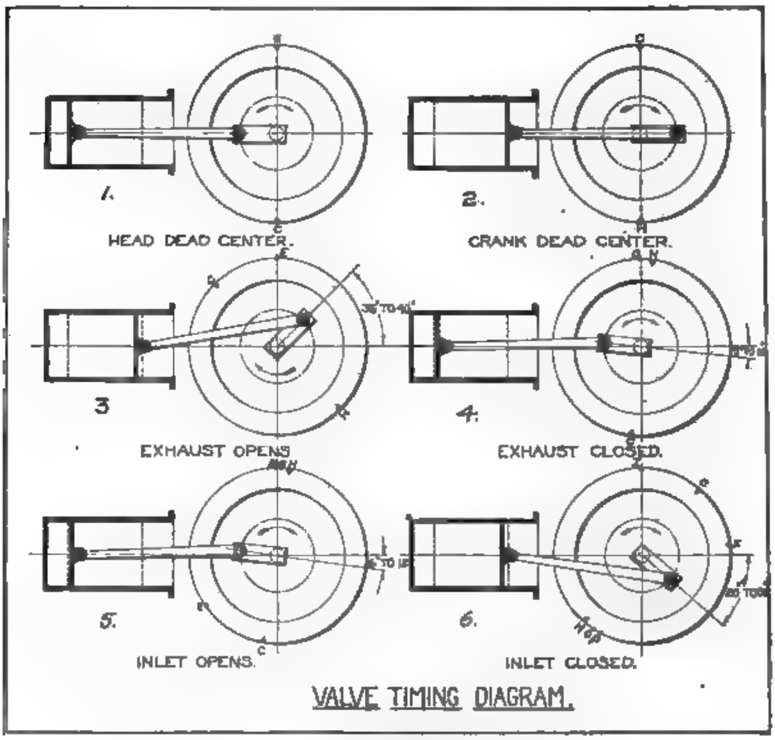



FIG. 211.—Faurote's Valve-Timing Diagram, showing Timing of Valves for One-Cylinder Engine.

wheel, the former method for setting valves has been almost universally adopted.

"As soon as the engine is finished, two marks, diametrically opposite, are located on the rim of the fly-wheel, such that when one is directly over the centre of the main shaft, the piston will be at one end of its stroke, or in other words, when either of these marks is on top, the piston will be on one of its 'dead centres.'

"Referring to Fig. 211, you will note that when the mark, *H*, passes a vertical line drawn through the centre of the shaft, the piston has just reached the outer end of its stroke, and when the mark, *C*, comes into this position then the opposite condition is true. These points, as mentioned before, are respectfully the *head* and *crank-end* 'dead centres.'

"Experiments have shown that the exhaust valve should open about 35 or 40 degrees before the crank arrives at the 'crank-end dead centre.' Therefore, No. 3 shows, approximately, relative positions of crank and piston when this opening should occur. In order to mark this position a line is drawn across the fly-wheel at the point, *E*. Next, as the closing should take place from 5 to 10 degrees late, that is after passing the 'head-end dead centre,' the point, *O*, is located, as represented in this position.

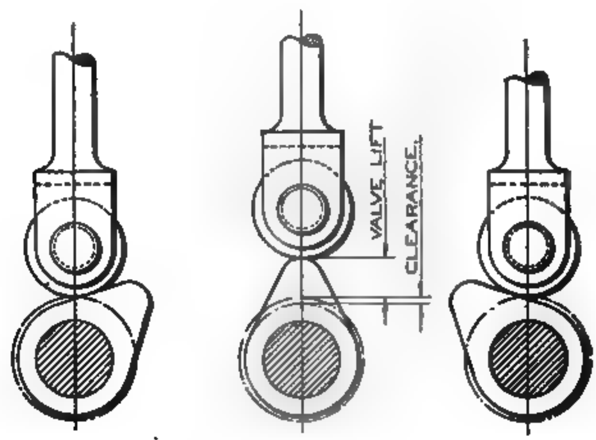



FIG 212.—The Successive Positions of a Valve-lifting Cam (after Faurote).

The inlet, of course, opens immediately after the exhaust closes, so that the point, *P*, is next marked off a short distance back of *O*. Lastly, the time of closing the inlet is determined (this varies from 20 to 50 degrees after crank has passed the 'crank-end dead centre') and the point, *I*, is settled upon.

"Having located correctly all points of opening and closing of valves, we are ready to proceed with the timing. Glancing at Fig. 212, you will notice that No. 1 shows the cam just about to raise the plunger which operates the valve; No. 2 shows the valve at its highest point, or maximum lift, and No. 3, the position of the cam and roller at the point of closing. You will notice that a small amount of clearance is left, in order

to insure a proper seating of the valve, when the cam has left the roller. It will easily be seen that as soon as the cam has turned far enough to cause friction between itself and the roller, the plunger will begin lifting the valve. As long as the roller turns freely it may be assumed that the valve is resting on its seat, but as soon as it appears to turn hard it is taken for granted that the valve is beginning to open. Naturally, when the cam is leaving the roller, the reverse is true.

"Now let us return to our original proposition, and see what use can be made of all this. We will first turn the fly-wheel over with the starting crank until the point, *E*, is directly over the centre of the crank-shaft. According to our calculations, the exhaust valve should be on the point of opening. Place your hand on the roller at the bottom of the valve plunger, and see whether or not it turns freely. If you find that it moves easily, turn the engine a little further in the direction of the arrow. A slight movement should cause the roller to tighten; if it does not, it shows that the cam has not yet come in contact with it, and hence the valve will not open soon enough. In this case turn the wheel back to its former position, and move the cam back around the cam shaft until the valve begins to open at the proper time. Frequently, in doing this, however, you will find that it will be impossible to make the valve close properly, and in that case it is necessary to braze a small piece on the side of the cam to increase its width in order to hold the valve open its required time. Having adjusted the opening, turn the fly-wheel around until the mark, *O*, shows up on top, and proceed in a similar way to find whether or not the roller frees itself at the right moment.

"Assuming that the exhaust valve has been satisfactorily disposed of, let us direct our attention to the inlet. Turn the fly-wheel over as before until the point, *P*, is just over the shaft. Then try the roller to see if it is just beginning to stick. If this is true, we can go on; if not, the same method of procedure has to be followed as in the case of the exhaust valve. When the time for the opening has been adjusted correctly, revolve the wheel until the mark, *I*, comes into position, when, of course, the roller should begin to loosen. After a little practice, by simply changing the shape of the cam, either by filing off or adding to its surface, you will be able to secure the results desired.

"Each engine requires a slightly different valve-timing, so it is impossible to give definite data regarding the above. Each manufacturer furnishes an instruction book which gives detailed information regarding proper valve-timing to be used for any particular size of motor. The diagram (Fig. 211) may be made of considerable assistance by properly substituting the values of angles given in the instruction book."

In timing the valves of a multiple-cylinder engine, this process must, of course, be repeated for each separate cylinder.

## CHAPTER TWENTY-SEVEN.

### GOVERNING AND CONTROL OF A GASOLINE ENGINE.

**Varieties of Controlling Device.**—For the governing of four-cycle engines several different methods have been employed. They are:

1. Hit-and-Miss Governors.
2. Throttle Governors.
3. Ignition Control.

In addition to these may be mentioned such devices as the Winton pneumatic control, which may justly be awarded first place in its class.

**Theories of Governing.**—Classifying governing apparatus according to the operative theories involved, we have:

1. Valve-lift regulation.
2. Variation of the fuel mixture.
3. Timing of the ignition.

With any one of these means are generally provided for both automatic and intelligent control Although, at the present time, many authorities contend that all control of an automobile engine should be solely in the hand of the driver, automatic governors still hold their place on most of the best-known makes of engine.

**Hit-and-Miss Governing.**—The original Daimler engines were controlled by what is known as the "hit-and-miss" form of governor. Briefly described, the theory is that, at excessively high speeds, the action of the exhaust valve is interrupted by a mechanism which withdraws the cam-actuated push-rod out of its line, causing it to *miss*. At normal speeds the push-rod always *hits* the end of the valve stem, pushing the valve open against the tension of its spring. In the earlier models of Daimler's V-shaped engine the opening of the exhaust valve was controlled by a feather running in a double eccentric circular cam

groove on the face of one of the crank disks, as shown in the half-sectional diagram. By means of a switch actuated by a sliding sleeve and centrifugal ball governor, the feather could be shunted from its course, so as to run in a nearly circular path, thus involving that the attached push-rod neither rises nor falls, and keeping the exhaust valve closed. This involved that the burned-out gases could not escape from the cylinder; also, that

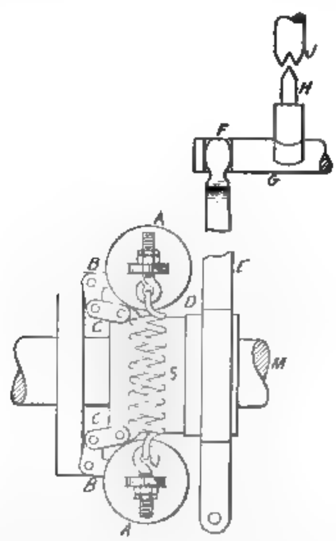
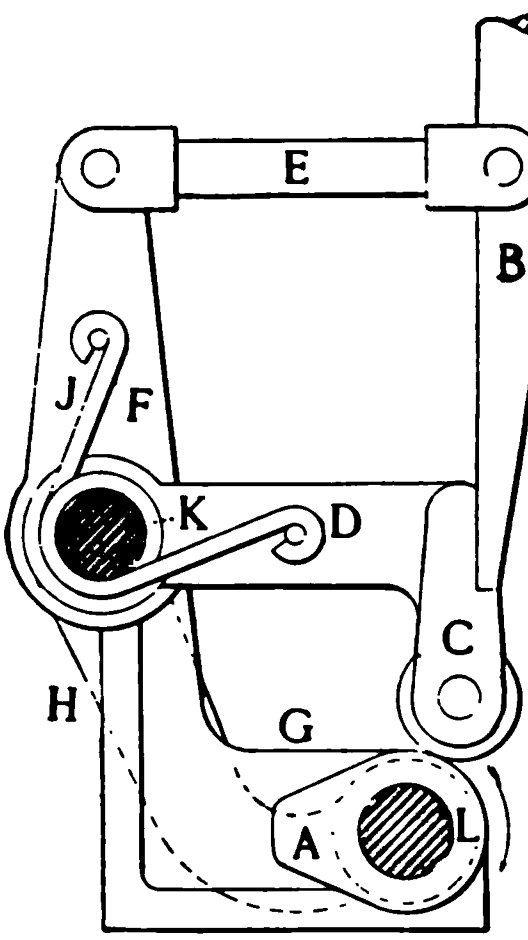



FIG. 213.—One type of Gas Engine Governor, which is an improved variation of the device used on the early Daimler motors. The parts are as follows: A and A, ball weights; B and B, bell cranks actuating the links, C and C, as the balls move outward resisting the tension of spring, S, and sliding sleeve, D, on the shaft, M. E is a lever arm attached to D, which moves the shaft, G, by contact at F, as shown, thus throwing the pick blade, H, out of contact with the end, J, of the exhaust valve rod.

no fresh charge could be taken in, the motor operation being suspended until the speed should fall to the proper rate.

In later models of Daimler engine a hit-and-miss governor of a different description was used, its object being to draw the push-rod away from the line in which it could hit and actuate the valve stem. As shown in an accompanying figure, the cam, *A,* rotated on shaft, *L,* bears upon the roller, *C,* and lifts the arm, *D,* pivoted at *K,* and held in position by a spring, *L*. By lifting arm, *D,* it also lifts pushrod, *B,* which opens the exhaust valve.

When, however, the speed of the motor has increased beyond the predetermined limit a sleeve of varying diameter, sliding on the same shaft, *L*, is slid along, so that the larger diameter is brought to bear against the downward extension, *H*, of the arm, *F*, thus causing *F* to incline on the pivot, *K*, toward the cylinder (at the right as in the cut), hence pushing rod, *B*, by link, *E*, out of range of arm, *D*, as it is moved upward by impulse from cam, *A*. In this case the exhaust valve is not opened.



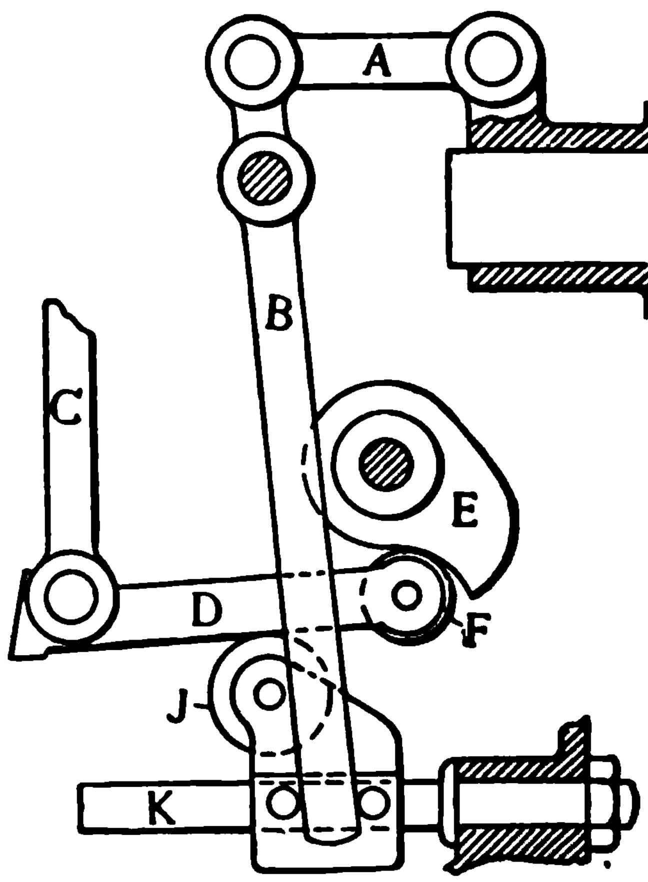




FIG. 214.—Hit and Miss Governor Mechanism of the later Daimler Motors.
FIG. 215.—Mechanism of the Peugeot Variable Exhaust Valve Lift.

**Governing by Variable Valve Lift.**—The Peugeots introduced another form of exhaust valve control apparatus, which, instead of operating to keep the valve closed, thus involving the difficulties incident on retaining the exhaust gases in the cylinder, gave a varying lift, according to the speed of the engine. As shown in figure 215, *A* is a link attached to spool, *G*, which is slid on shaft, *H*, as the governor works under speed of rotation. *A* actuates the lever, *B*, sliding the roller, *J*, on shaft, *K*, and thus moving the fulcrum of lever, *D*, varies the lift of pushrod, *C*, which receives its motion from cam, *E*, bearing upon roller, *F*.

**Governing by Varying Charge Volume.**—Instead of interrupting the movement of the exhaust valve, several engineers, notably Winton, Duryea and Mors, adopted the theory of govern-

ing by controlling the intake, and thus varying the volume of the fuel charge admitted to the cylinder. By this means the operation of the engine may be maintained at any desired point of speed or power. As shown in the diagram of the Mors engine, the centrifugal governor actuates a horizontal valve shaft, which, in turn, throws levers controlling cocks for varying the fuel supply admitted to the intake valves. A very similar arrangement is embodied on the Duryea three-cylinder engine, with the notable exception that hand control takes the place of automatic governing.

**Winton's Pneumatic Governor.**—Winton's governor controls the volume of the charge by varying the lift of the inlet valve. It may be operated both automatically and manually, and may be so adjusted that the engine can operate at any desired rate of speed, without interference. Each inlet valve has an elongated stem, which extends backward so as to carry the piston of a small cylinder to the rear of the valve chamber. A reciprocating air pump supplies air to this small cylinder, varying the travel of its piston, according to the speed of the engine. At high speeds the air pump works rapidly, greatly compressing the air before the small piston, and consequently opposing the free opening of the inlet valve; at low speeds, it works slower, allowing greater freedom to the inlet opening. Of course, with the pump working direct from the engine and constantly increasing the air pressure within the small cylinder, the point would soon be reached at which the inlet valve could not open and the operation of the engine must cease. To forestall this difficulty, a "set governor" or regulating cock is provided, for the purpose of allowing a certain proportion of the air to escape from the small cylinder, thus making the rate of speed constant at any desired point. Furthermore, there is another regulating vent cock, controlled by a push button at the driver's foot, which enables him to increase the speed to the point of allowing the air to escape as fast as it comes from the pump, thus removing all obstruction to the lift of the inlet valve.

The details of the Winton governor are given in the accompanying diagram. Here, air compressor piston, *P*, is driven directly from one of the motor pistons, and forces air past the check valve, *V*, into the compressed air cylinder, where it operates to hold the piston to the left, and keeps the intaking valve closed, regardless of the piston suction tending to open the valve by moving it to the right. By means of the regulating cock the pressure may be reduced in the air cylinder, thus permitting the intake valve to open, more or less as the air pressure is more or less

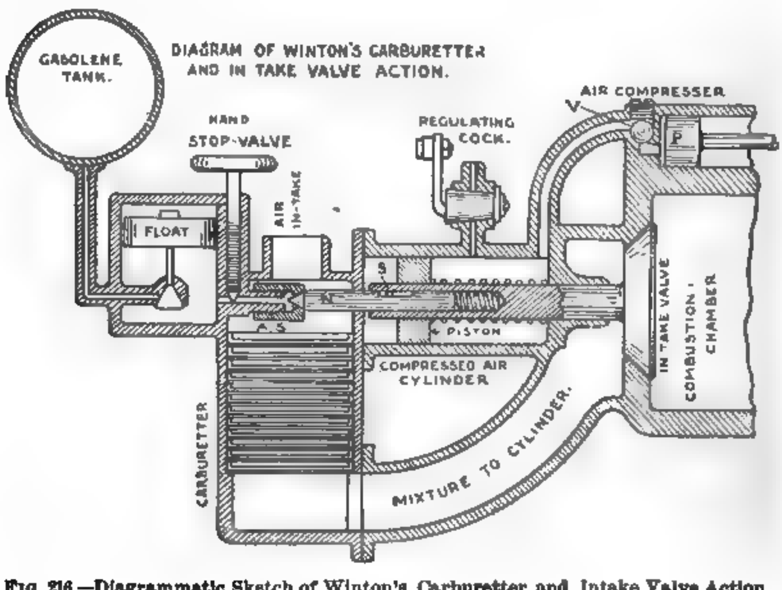



**Fig. 216.—Diagrammatic Sketch of Winton's Carburetter and Intake Valve Action, as applied to an Horizontal Cylinder Engine.**

reduced in the cylinder. The needle valve, *N*, is seated in and carried by the intake valve stem, is spring pressed to the left by a coiled spring at its right end, is retained by a cross pin, *S*, and co-acts with the adjustable seat, *A*, *S*, to close or open the passage of gasoline from the float chamber to the carburetter underneath, whence the mixture is drawn to the cylinder through the intake valve. No gasoline can go to the carburetter unless the motor piston is moved, and more or less gasoline goes to the car-

buretter as the intake valve is lifted more or less. The regulating cock governs the action of the motor by determining the amount of air that is allowed to escape through the vent.

**Cadillac Variable Valve-Lift.**—An automatic governing device, which varies the lift of the inlet and exhaust valves in a manner analogous to that adopted by Winton is used with the Cadillac four-cylinder engine. In this device, the pressure of a liquid is used to vary the lifts of the variable valve cams fixed on a rotating countershaft, as shown in Fig. 217. As here shown, the regulation is accomplished by sliding the cam shaft endwise. The device is described, as follows:

*C* is a portion of the cam shaft showing two of the cams: *A*,

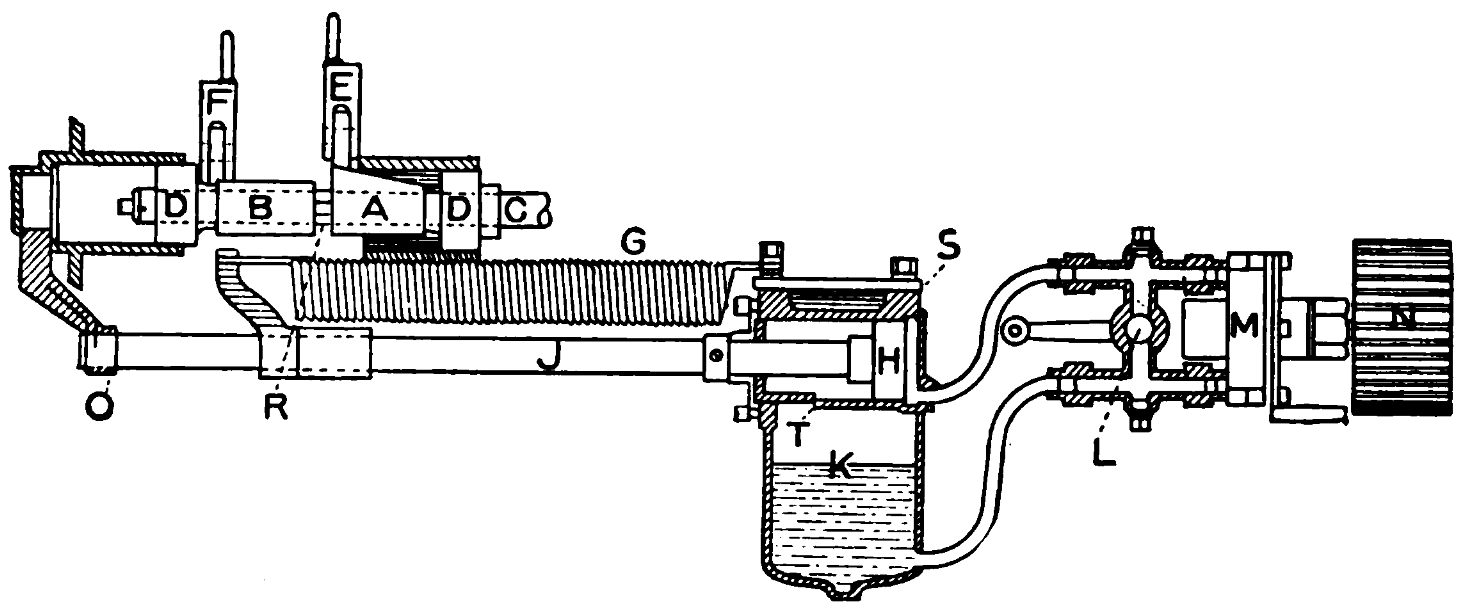



FIG. 217.—Diagram of the Cadillac Variable-Cam Oil-Governor Regulation.

an inlet cam operating the inlet valve through the roll and valve-lifter, *E*; *B*, an exhaust cam, operating an exhaust valve through the roll and valve-lifter *F*. *D*, *D* are two bearings for the cam-shaft *C*, which are also free to move in the bored-out parts of the motor frame. *R* is a hardened steel finger with its end between the exhaust cam, *B*, and the inlet cam, *A*. *R* is carried on the piston rod, *J*, which is attached to the piston head, *H*. The piston and rod, and with them the finger, *R*, and the cam shaft, *C*, are all normally held in the position shown by the coil spring, *G*. With the cam shaft in this position the inlet cam, *A*, gives the maximum lift to the inlet valve, allowing the motor to develop its full power and speed. *M* is an oil pump

driven by the gear, *N*. The pump, *M*, draws its supply from the well, *K*, and discharges into the closed end of the cylinder, *S*. This discharge is governed by the by-pass, *L*. If L be closed and the motor started, the pump, *M*, discharging into the cylinder, *S*, will force the piston, *H*, out until it uncovers the edge of the discharge port, *T*, and allowing the oil to flow back into the well, *K*. Under these conditions the cam shaft, *C*, is held at the other extreme of its travel so that the inlet cam, *A*, causes a very slight lift of the inlet valve, giving the minimum speed and power from the motor. If the by-pass, *L*, be partly open, the tension of the coil spring, *G*, will carry the cam shaft back, until

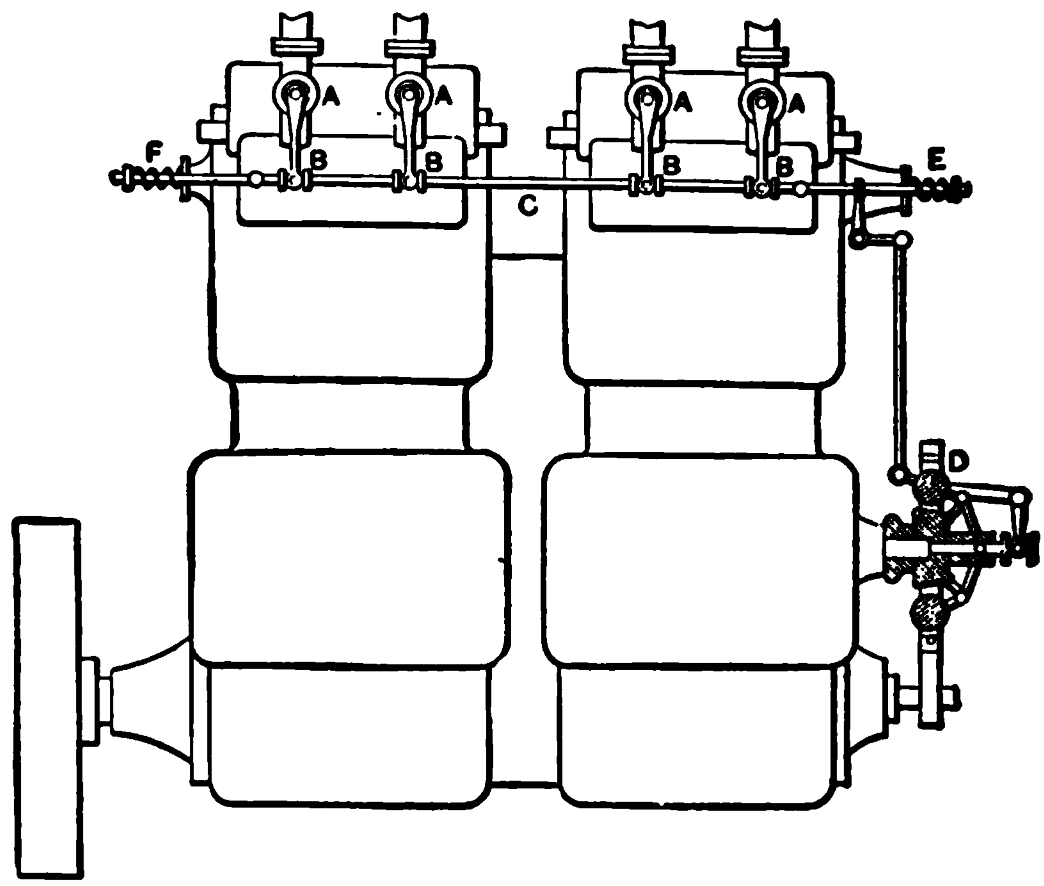



FIG. 218.—Diagram of Volume Throttling Device on the Mors Engine. A and A are throttle valves on the inlet pipes; B and B, valve levers; C, valve shaft, under control of the governor, D; E and F, springs, used either singly or together, according to control, so as to vary the opening of the inlet. System like the Duryea.

the speed of the motor increases, so that the discharge from the pump, *M*, balances the tension of the spring, *G*, in spite of the opening of the by-pass, *L*. It will be seen that under these conditions, if the load of the motor is increased the reduction in speed will immediately result in an increased lift of the inlet valve, allowing the motor to develop greater power to meet the increased demand. If the load on the motor be decreased, the increase in speed will cause the inlet valve to receive less lift, thus

reducing the power of the motor according to the reduced demand upon it.

**Varying Mixture and Varying Volume.**—Winton claims, as the most conspicuous advantage of his pneumatic control, that the quality or air and gas proportions, of the fuel mixture are constant at any predetermined point of carburetter regulation, and that the volume only is varied, thus supplying fuel as required and effecting a great economy. With reduced volume the

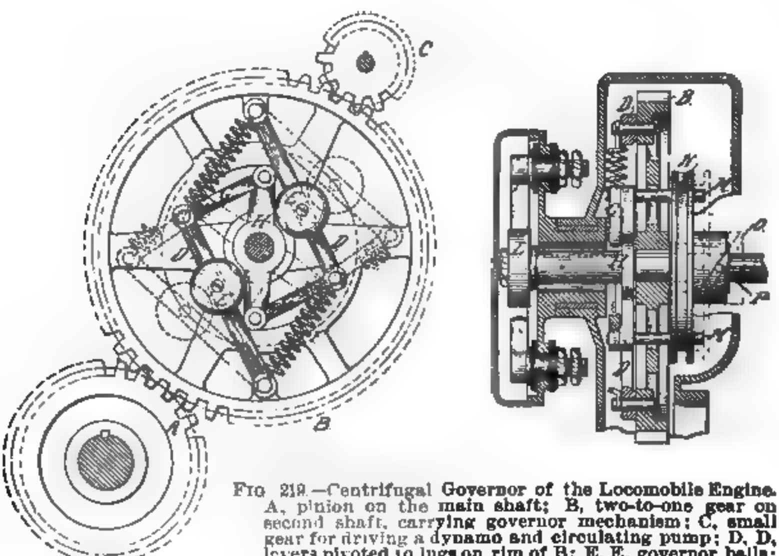


FIG. 219.—Centrifugal Governor of the Locomobile Engine. A, pinion on the main shaft; B, two-to-one gear on second shaft, carrying governor mechanism; C, small gear for driving a dynamo and circulating pump; D, D, levers pivoted to lugs on rim of B; E, E, governor balls; F, F, governor springs; G, G, links connecting lever arms to double armed bracket. H, turning it when the balls fly out to positions shown by dotted lines; L, commutator wheel of ignition circuit-maker; M, M, lateral studs on bracket, H; N, grooved collar rotated by studs; O, sleeve on N, having a spiral slot which works on pin, P.

initial and compression pressures are also reduced. As against "volume throttling," however, very many engineers still adhere to the theory of varying mixture, reducing excessive speeds by allowing greater proportions of air to enter the mixing chamber, and increasing the proportion of gas as the speed falls. This practice involves, of course, that the same volume of fuel mixture

is always admitted to the cylinder, and, consequently, that the initial and compression pressures are invariable. The two theories are one in point of reducing the explosion pressure, in order to reduce speed.

**The Riker Governor.**—The governor used on the Locomobile gasoline engine, for automatically effecting the throttling of the carburetter and the retarding of the spark, is a good example of it class. As shown in the accompanying diagrams, the arms carrying the governor weight actuate links at right angles to their normal position, and cause a sleeve on the governor shaft to turn on the shaft through part of a revolution, according to the speed

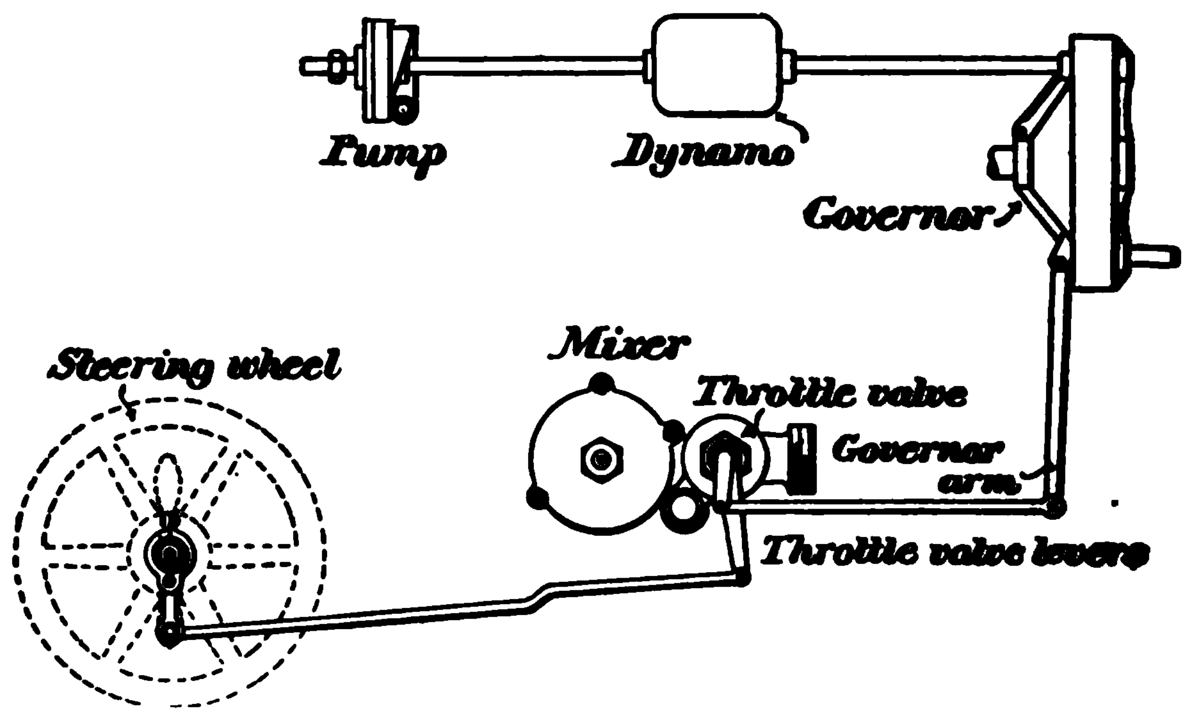



FIG. 220.—Diagram of the Governor and Control Connections of the Locomobile Engine, showing manner of automatically and manually throttling the carburetter.

of the engine. The part rotation of this sleeve serves to retard the spark by shifting the contact of the sparking commutator. At the same time, two pins, attached to the sleeve arms and projecting through the gear into the opposite direction, give a similar turn to the governor shipper loosely let on to the governor shaft. This shipper has a hub with a spiral groove, through which projects a pin fixed into the shaft, as shown. By the part revolution given the shipper by the pins the hub moves backward along the shaft as far as the pin in the groove will allow it. thus actuating a link for throttling the carburetter. As the engine

slows down, the sleeve holding the commutator cam returns to its position, and the pins, acting on the shipper, moves the slotted hub into normal position, restoring the full feed of fuel mixture. In starting the engine, the driver reverses the lead, retarding the spark until the full speed is attained, then leaving control to the governor.

**Throttling the Fuel Mixture.**—In practical operation the fuel mixture is throttled by a valve operated directly by an arm actuated by the centrifugal governor. As shown in the several types of carburetter, described in another chapter, an important

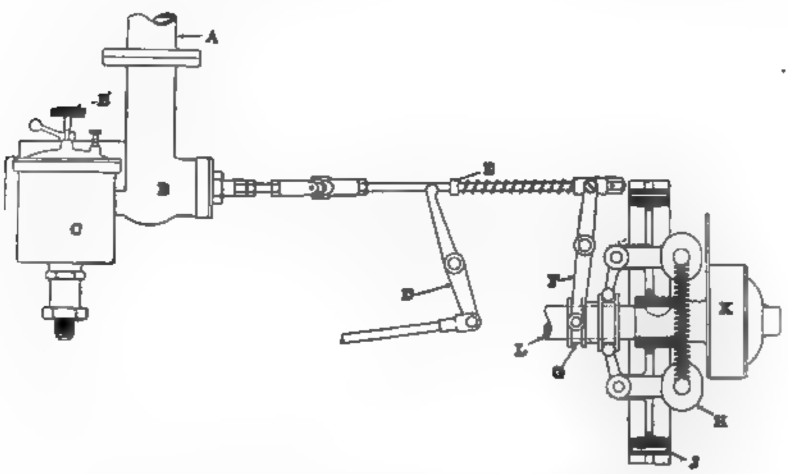



**FIG. 221.—Automatic Governor and Hand Throttling Connections of the Toledo Engine.** The parts are: A, the suction pipe of the carburetter; B, the carburetter; B', the needle valve on the float chamber; C, the float chamber; D, throttle controller on rod, E; F, the governor lever; G, the sliding governor sleeve; H, governor weight; J, fibre gear on cam shaft; K, sparking commutator; L, cam shaft.

part in the work of governing the engine takes place in the mixing chamber. In all devices for automatically regulating the air-intake of the carburetter, the means adopted is, briefly, some form of sliding or rotating valve for varying the opening of inlet tube. Accurate adjustment of the valve for the particular fuel to be used fixes the maximum and minimum openings at such points that the resulting mixtures of air and fuel gas are always within the explodable limits. The result is that a greater proportion of

air is admitted at a high speed, and, consequently, the power effect of the explosion is decreased. As the speed falls, the opening of the air inlet is decreased, and, consequently, the power effect of the explosion is augmented.

**Varying the Point of Ignition.**—Another effective method of controlling the speed of the engine, is retarding of the spark. In practice, this involves some means for connecting the governor to the rotating member of the "commutator" or contact-breaker, so as to produce the igniting spark at the desired point in the cycle.

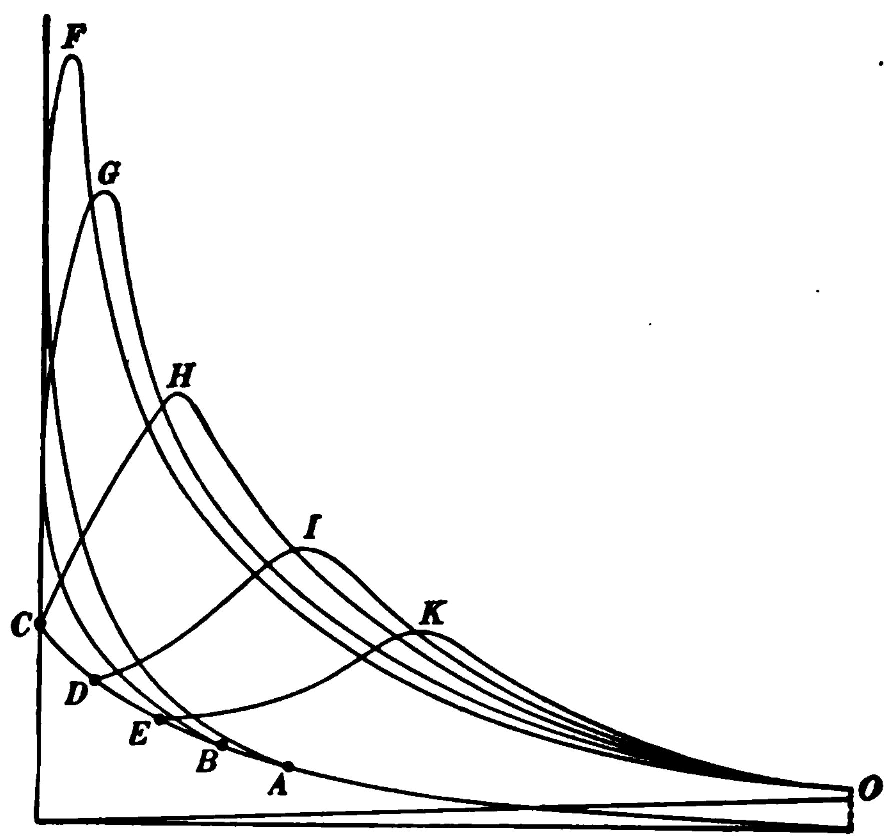



FIG. 222.—Composite Indicator Card for a Gas Engine, showing varying explosion pressures due to varying the time of the spark. A and B are ahead; C on dead centre; D and E, back of centre

**The Correct Time for Ignition.**—As with other matters connected with the control of gasoline engines, the time of the spark may be varied only between very definite limits. In general, these limits are between one-third stroke ahead and one-seventh stroke after the dead centre of the crank, according to the kind of fuel, the strength of the mixture and the normal speed of the engine. If it occurs too early, the point of maximum pressure is reached before the compression stroke is completed, and very frequently a "back-kick," or tendency to reversal of the motion follows; certainly a complete waste of the power effort. If it occurs

too late, the maximum pressure is reached only when the stroke is far advanced, with the result that a large part of the power effect is lost. It is desirable, however, that the point of maximum pressure should not occur on the dead centre of the crank, since this produces a wholly unnecessary jar and friction on the crank pin, and, as in the two previous cases, wastes the power. Under usual conditions, the point of maximum pressure, or complete ignition, should occur at the beginning of the out-stroke of the piston.

**Spark-Timing and Power Effect.**—The effects obtained by varying the time of ignition with a constant mixture are shown by the accompanying diagram given by an English authority. Here the points, *A, B, C, D, E,* are taken at the moment of spark ignition, and the points, *F, G, H, J, K,* at the point of greatest pressure. The point, *A,* is about one-third stroke ahead of dead centre; *B,* about one-fourth ahead; *C,* on the dead centre; *D,* one-sixteenth after; *E,* one-seventh after. The curves, *AF, BG, CH, DJ, EK,* show graphically the relative power effort to be obtained by varying the spark from positive to negative lead.

**Spark-Regulation and Speed.**—The field for the most frequent application of engine governing by spark regulation is found in the practice of shifting the point of ignition, so as to enable the maintenance of high speeds. This is true for two very definite reasons:

1. With ordinary forms of jump and break spark, the fuel ignites progressively, instead of detonating, or exploding, consequently entailing the lapse of an appreciable period before the maximum pressure is reached.

2. The spark on a high-tension circuit always occurs at a point measurably later than the closure of the primary circuit.

At high speeds, therefore, the time of circuit-closing is advanced in proportion to the number of revolutions per minute, in order to begin the out-stroke as nearly as possible at maximum pressure. This is illustrated in the accompanying diagram from *Technics,*

which shows average points for circuit-closure or spark-timing: for hand-starting at *A;* for slow running at *B;* for full load at 400 R. P. M. at *C;* for full load at 1,200 R. P. M. at *D;* for very light load at about 400 R. P. M. at *E*. The situation is set forth, as follows:

"Many attempts have been made to render timing automatic, but up to the present none of these has proved satisfactory. To appreciate the difficulties involved it is necessary to consider all the causes that render variation necessary. It is found that, as an engine runs faster, the point of sparking has to be advanced, so as to cause it to occur earlier, and, when an engine is running very fast, it is necessary for the theoretical

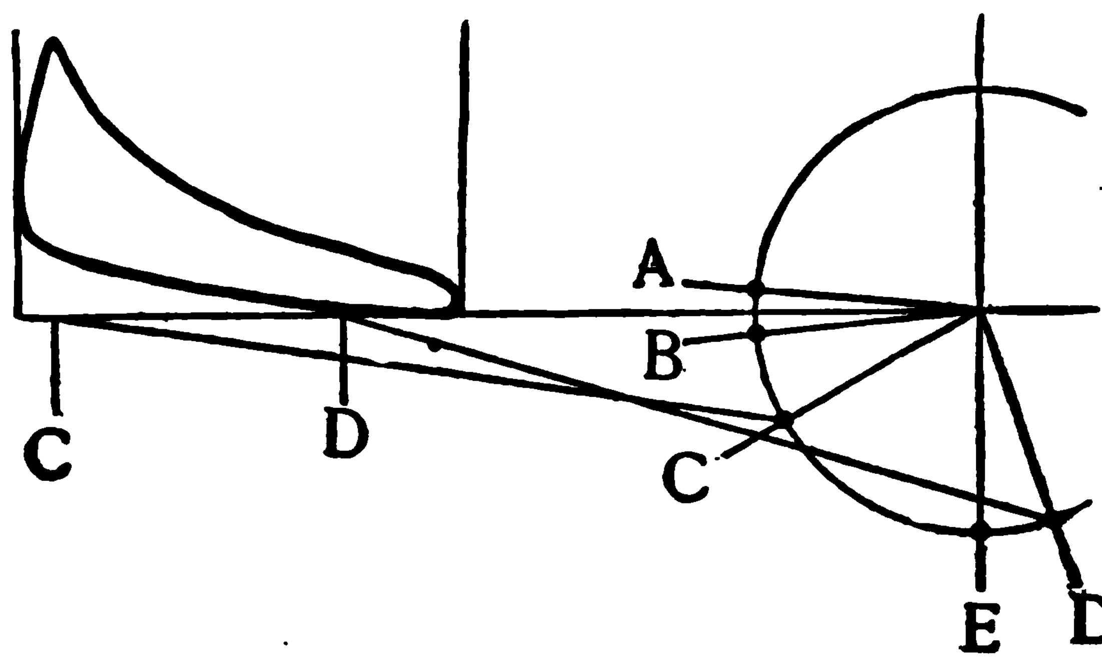



FIG. 223.—Diagram showing Proper Points for Closing the Ignition Circuit at Various Speeds and Loads: A, point of ignition for hand starting; B, point of ignition for very slow running; C, point of ignition for full load at about 400 r.p.m.; D, point of ignition for full load at about 1,200 r.p.m.; E, approximate point of ignition for very light load at about 400 r.p.m.

point of ignition to be even as early as 110° of crank travel before the firing center.

"The principal reason for this is the interval of time between the first ignition of the gas and the instant when maximum pressure is reached; this interval, being approximately constant, renders it necessary to advance the point of ignition as the engine speed increases, if it is desired to keep the point of maximum pressure at the beginning of the working stroke. Two other causes add to this effect—the lag of the trembler on the induction coil, and the lessened compression at high speeds, due to the loss of volumetric efficiency caused by the wire-drawing effect of both induction and exhaust valves. These are slightly compensated for by the quicker burning of the richer mixture, taken in at high speeds, caused by the increased vacuum in the jet chamber. It is evident that the coil lag is a time-element and that the interval between the completion of the electric

circuit and the "break," due to the downward movement of the trembler, will be constant for the same coil, and quite independent of the engine speed. This factor is of less importance since the general adoption of high speed tremblers, and is, of course, entirely absent in magneto ignition. The loss of volumetric efficiency results in more burnt gas being left in the cylinder from the previous explosion, and the taking-in of a lessened charge, causing a drop in the compression and consequent slower burning, as the degree of compression has considerable influence on the rate of burning of an explosive mixture of given quality. The enriching of the mixture at high speeds compensates for this to a certain extent, depending on the efficiency of the valve gear and carburetter, but, of course, this compensation is only at the sacrifice of fuel efficiency.

"From the foregoing remarks it will be evident that if the mixture is throttled, thus lowering the compression, it will be necessary to advance the spark to obtain a correct diagram at the same engine speed; and this effect will generally be intensified, as throttling usually results in a weakened mixture. Any automatic device must, therefore, not only vary the contact to compensate for variation of engine speed, but, if correct ignition and maximum efficiency is desired, also for varying degrees of throttling and alterations of quality of mixture."

**Spark and Throttle Governors.**—As may be readily understood, governing by retarding the spark is very wasteful of energy, since it results inevitably in exhausting before ignition is complete. For this reason, when spark regulation is used in automatic governing, it is generally in connection with mixture-throttling, which doubly reduces the power effect. In general, however, precisely the same result follows with the use of a weak mixture as with the use of a retarded spark—reduced power effect and slow combustion of the charge. A rich mixture and a positive lead to the spark alike produce increased power effect and rapid combustion. The diagram, shown in Fig. 222, could be produced as the result of varying the fuel mixture, as readily as by shifting the time of the spark-occurrence.

The diagram in Fig. 223 shows that the best effect of the exploding fuel may be obtained only by advancing the spark when desiring to run at high speeds. In order to achieve this end, several cars, notably the Jeffrey Rambler, are equipped with an automatic spark-advance governor.

## CHAPTER TWENTY-EIGHT.

### HINTS ON THE CARE AND OPERATION OF GASOLINE VEHICLES.

**Gasoline Engine Manipulation.**—The first and most important thing in operating a motor carriage is, of course, the engine and its management.

This includes, not only the necessary conditions of operation and control, which are simple to state, but also the numerous disorders and mishaps that may be encountered:

1. From faulty construction, which, however, will be seldom experienced with well-made motor carriages.

2. From careless or ignorant handling, such as:

   *a*. Insufficient lubrication;

   *b*. Faulty adjustments;

   *c*. Exhaustion of the fuel, current or jacket water;

   *d*. Racing;

   *e*. Over-heating.

3. From any one of a number of disorders in the electrical apparatus.

4. From poor gasoline, or faulty adjustment of the carburetter.

5. From worn or broken parts.

By far the greater proportion of gas-engine troubles result from some derangement of the sparking apparatus. Second in importance come troubles with the fuel mixture. Both electrical apparatus and carburetter may require attention.

**Electrical Adjustments.**—Since the electrical apparatus is likely to give the most trouble to the average motor-carriage driver, it is well to specify the parts that may prove seats of trouble, and should be periodically examined. The following is a summary of such parts:

1. *The battery,* primary dry cells, accumulator, or mechanical generator.

2. *The coil;* its connections, wiring and the vibrator, if one is fitted.

3. *The commutator,* or contact-breaker, according to the variety of circuit used.

4. *The spark plug.*

5. *All wiring and connections.*

**Electrical Cells and Sources.**—Many small vehicles obtain all the sparking current from primary dry cells. Most large vehicles use chemical cells, primary or secondary, merely for starting, being provided with a magneto-generator or small dynamo that is automatically switched into circuit when the engine has attained sufficient speed to generate the current.

**Primary Dry Cells.**—Dry cells, when used as a source of current for sparking, particularly for extended periods, should be arranged in series in two or more separate batteries, with switches that may cut all out of circuit, except the one in use as current supply. The reason for this is that such cells are subject to deterioration in use, and a new battery should always be at hand.

Deterioration may result:

1. From extensive use, after which the cell becomes exhausted through consumption of the zinc element, or the electrolyte.

2. From short circuits long continued, which cause the cell to run out of current more rapidly than othewise. A *temporary* short circuit will not injure a dry cell as seriously as some other types of source. Generally, it will polarize it more quickly. A season on open circuit will find it still serviceable.

**Short Circuits.**—A short circuit sometimes results from defective insulation at some points on the wiring, enabling contact with metal parts and producing a low-resistance leak.

In manv cases, it results simply from neglect to open the switch or the primary circuit, on stopping the engine. If, then, there

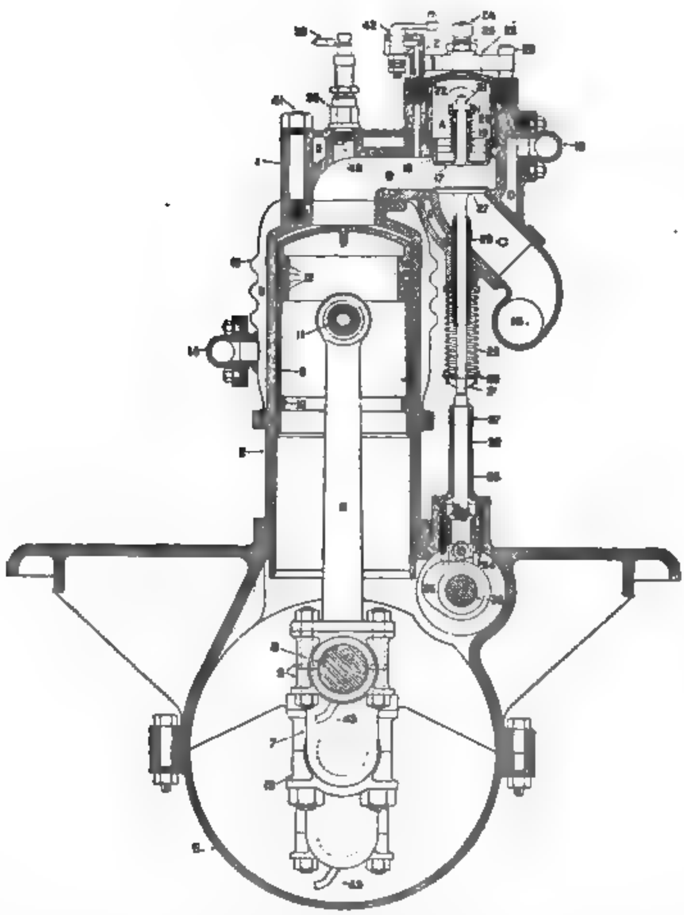


FIG. 234. Section through One Cylinder of an Automobile Engine (Pope-Toledo), operated by automatic inlet. The parts are: 1, cylinder head; 2, cylinder; 3, piston; 4, crank case, upper half; 5, crank case, lower half; 6, connecting rod; 7, crank arm; 8, crank pin; 9, crank brasses; 10, crank shaft bearing; 11, piston pin; 12, piston rings; 13, water jacket casing; 14, water inlet pipe; 15, water outlet pipe; 16, exhaust pipe; 17, inlet valve; 18, inlet valve seating; 19, inlet valve spring; 20, inlet valve spring retainer; 21, inlet valve spring retainer key; 22, inlet valve cap; 23, inlet valve yoke; 24, inlet valve set screw; 25, inlet valve set screw lock nut; 26, inlet valve yoke stub; 27, exhaust valve; 28, exhaust valve stem bushing; 29, exhaust valve spring; 30, exhaust valve spring retainer; 31, exhaust valve spring retainer key; 32, exhaust valve push rod; 33, exhaust valve push rod guide; 34, exhaust cam roller; 35, exhaust cam; 36, exhaust cam shaft; 37, dust cap; 38, sparking plug; 39, sparking terminal; 40, sparking points; 41, cylinder head studs; 42, relief cock; 43, oil scoop; A, inlet chamber; B, compression space; C, exhaust passage; D, water space.

is a leak, or the contact is on the commutator the current will rapidly run to waste.

**The Polarization of Dry Cells.**—Dry cells, so-called, are all of the "open-circuit" variety. That is to say, the generation of current produces the condition known as "polarization," or the collection of hydrogen on the electrode attached to the positive lead wire. This condition may be remedied, the cell may be "depolarized," only by leaving it for a period on open circuit, or disconnected.

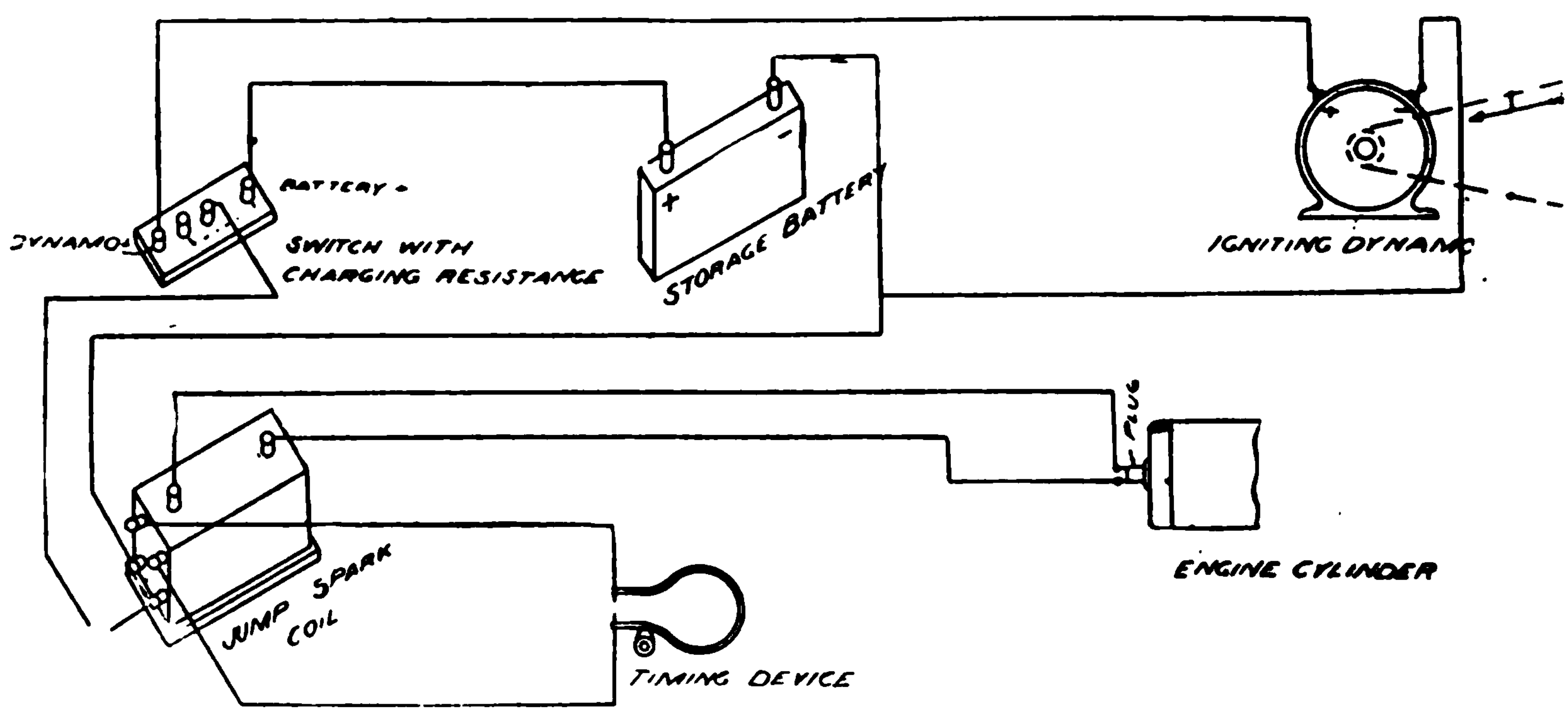



FIG. 225.—Ignition Circuit for a Single Cylinder, containing a Dynamo Generator and Storage Battery. Both terminals of the secondary winding of the induction coil have visible leads to the sparking plug.

A polarized cell will show a low current register on the ammeter, but may be restored more or less after resting.

**Storage Cells.**—The theory and management of storage cells are set forth in another chapter. Storage cells used on sparking circuits are often charged by the surplus current of the sparking dynamo. When no dynamo is used, they are charged by special attachments to electric feed mains, or by a battery of wet cells of proper voltage.

**Care of Storage Cells.**—In order that storage cells should continue of service in the sparking circuit of a gasoline engine, it is necessary to constantly observe the following rules:

1. Each cell should register at full charge about 2.5 volts and should never be used after the voltmeter falls to 1.75.

2. If short-circuited at any time, the cell should be immediately disconnected and recharged, as elsewhere specified. Short circuiting is one of the most fatal mishaps that can overtake a storage cell.

**Magnetos and Dynamos.**—As a rule, troubles with a mechanical generator are liable to arise from glazing or lack of adjust-

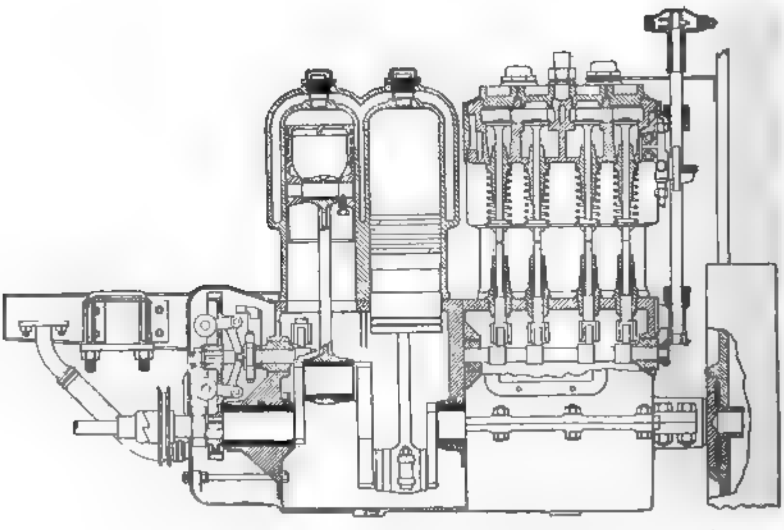


FIG. 236.—Part Sectional Elevation of the Packard Four-Cylinder Engine, showing method of driving the inlet and exhaust valves from a single cam shaft.

ment of the brushes and commutator. Next to this, the oil feed or bearings should be carefully watched and supplied, and the cut-out governor, if one is attached, should be occasionally examined, to be sure that it is in perfect working order.

**Glazing.**—A troublesome condition that occasionally appears in small dynamos is a glaze on the commutator or contact surfaces of the brushes. This may be removed from the brushes by

wrapping a very fine *sandpaper,* sand side up, around the commutator and rotating the spindle, so that the brush ends are thoroughly scoured. It may be removed from the commutator by rubbing the surface with the finest grade of sandpaper. *Emery paper* should never be used for this purpose, since emery, being carbon, is a conductor, and its presence between the segments of the commutator is liable to interfere with the insulation. It also causes rapid wear.

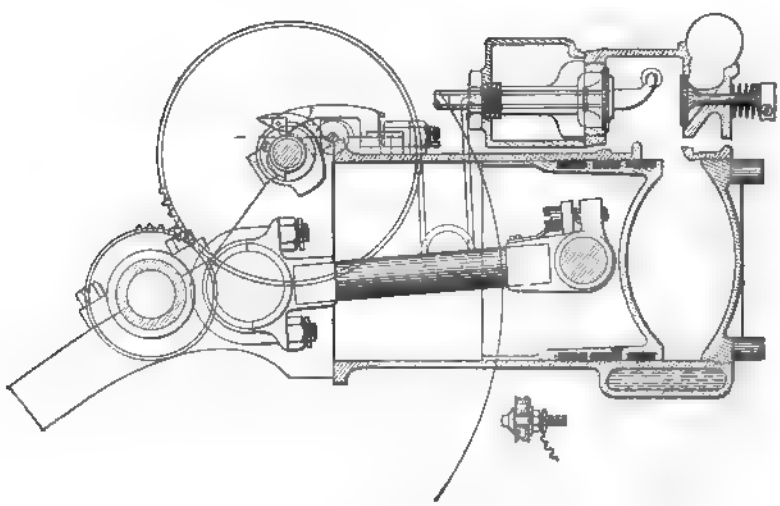


FIG. 227.—Sectional View through One Cylinder of the Duryea Three-Cylinder Engine, showing working parts. The exhaust cam operated by a two-to-one gear imparts a double motion to the valve pushrod; a lift for opening the valve, and a double twist for making and breaking the connections of the electrical spark. The valve and sparking chamber is projected so as to show the position of contained mechanism on a plane different from that of the cylinder section. Details of the insulated sparking anvil are shown below the cylinder. It is an iron contact point, having a mica washer on the inside and the outside of the cylinder walls, and a mica bushing between, so as to perfectly insulate it from the metal of the engine. A very short water jacket and the concave cylinder and piston heads are also exhibited in this figure.

**The Induction Coil.**—The coil generally needs very little attention. Provided the battery is maintained at an approximately even efficiency, and the coil is carefully protected from moisture, oil and dirt, there is virtually no danger of electrical derangement. It may be safely asserted that the majority of

cases in which the coil is supposed to be "worn out," are merely examples of irregular or inefficient action of the condenser. Occasionally a spark discharge from the condenser occurs at the moment of breaking contact of the vibrator and screw back stop with the result of burning the contacts. Dirt or oil between the vibrator contacts will produce similar result. In either case there will be no spark at the spark plug. Spark discharges at the vibrator contacts usually result from the condenser not being

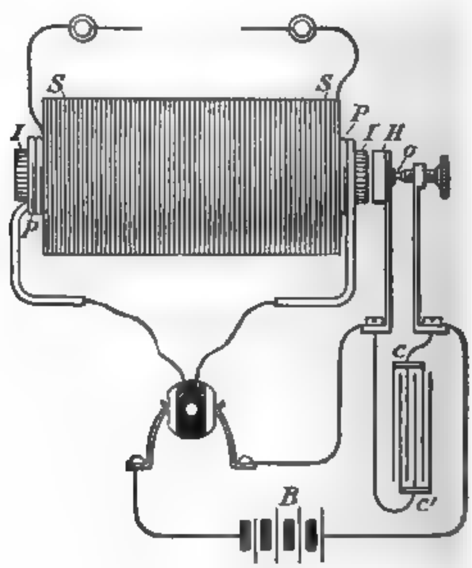



FIG. 228.—Diagram of the Essential Parts of an Induction Coil: B, chemical battery; C, C', condenser terminals; I, laminated iron core; P, primary winding; S, secondary winding; H, head of the vibrator; o, contact point of the back-stop screw.

suited to the battery. When the condensor is of proper size, the spark will be very minute.

**Moisture in the Coil.**—Nothing will so rapidly deteriorate a high-tension coil as the presence of moisture in its windings. The water frequently soaks through the insulation, short-circuiting the current and preventing a spark. A coil, evidently affected by moisture, can not be repaired, except by experienced workmen, and had best be replaced.

**Adjusting the Coil.**—In most cases, as the motorist is warned, the coil vibrator needs no adjustment. The principles of its operation should be understood, however:

1. When the adjusting, or back-stop screw is turned inward, forcing the vibrator nearer to the pole of the core, the rapidity of vibration will be increased.

2. When the adjusting screw is turned outward, increasing the distance between the vibrator and pole of the core, the rate of vibration will be decreased.

3. There are very definite limits to the proper operation of the core, at either loose or tight adjustment.

A fair adjustment for low speeds may prove unsuitable for high speeds, and *vice versa*.

A fair adjustment for a strong battery will probably be found unsuitable for a weak battery, and *vice versa*. Therefore, when possible, attend to the battery rather than to the coil adjustment.

With the use of a jump-spark coil, this is nearly the strongest argument for a double battery, controlled by a two-point switch.

4. If one cares to risk experiment with coil adjustments, he will soon discover the range of efficient action.

As a general proposition, the following rules hold good for adjustment of the coil:

1. The vibrator should vibrate with sufficient rapidity to give a distinctly musical sound.

2. Rapid vibration, except, of course, one that is excessive, is more efficient and better for the battery than one that is slower.

3. Reducing the rate of vibration increases the efficiency of a weak battery, according to the statements of some authorities. The truth of the matter is that reducing the rate of vibration enables a stronger spark by permitting the coil to saturate more fully.

As may be readily understood from the circuit description already given, the vibrator should sound only on the closure of the primary circuit, when the commutator is in operation. Con-

stant sounding of the vibrator indicates a leak or short circuit somewhere, and should be immediately investigated. A short circuit is the quickest means for exhausting a chemical battery. On the other hand, it means speedy destruction for a storage battery, as will be explained later.

**Vibrator Speed and Engine Operation.**—As will be evident on reflection and from previous explanations, the spark in cylinder does not occur at the same point in the piston stroke at high and low speeds, nor, ever necessarily, at the moment the primary circuit is made at the commutator contact. This is due partly to the vibrator and partly to the coil. Some time is always

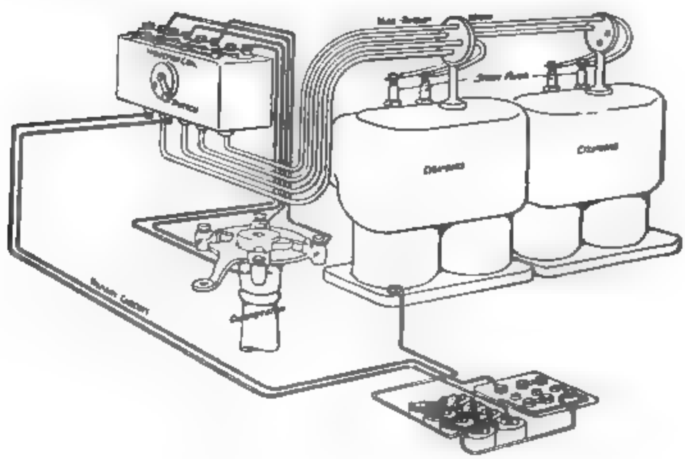


FIG. 229.—Wiring Lay-out for a Four-cylinder Engine, showing dry cell and secondary batteries, controlled by switch on coil-box.

required to saturate the coil, make the break and discharge the core, producing the jump spark. The average duration of these operations is about .005 second, which, although quite negligible at low speeds, requires progressive advances of the time as speed increases. The movement of the vibrator also consumes a fraction of a second, its speed being indicated by the pitch of its buzz, but unless the speed be very high, the time for occurrence of the spark is changed. If the vibrator be leaving contact with the core at the moment of circuit-making in the commu-

tator, the time of one vibration must elapse before the occurrence of the spark; if the vibator be in contact at this moment, the spark follows almost immediately. These facts enforce the desirability cf high-speed vibration.

In a multiple-cylinder engine using a separate coil for each cylinder, the vibrators should be tuned as nearly as possible to the same pitch or rate of vibration; otherwise the sparks will occur at different points of the several respective piston strokes.

**Choice of a Coil.**—In purchasing a coil for any make of carriage engine, it is necessary to see that it is perfectly suitable for the type of battery or generator in use. Induction coils, like other electric coils, are wound for use with a certain definite voltage in the primary source. Logically, therefore, the best effect can not be obtained unless the coil and source are mutually suited. This rule holds for all types of source, but it is particularly true when a small dynamo is used.

**The Commutator or Distributor.**—The commutator, so-called, should be examined occasionally for:

1. Loose screws or contacts.

2. Thick oil or dirt on contact surfaces.

In a wipe commutator only the thinnest and lightest grade of oil should be used on the contact surface.

Loose or foul contacts constitute a fertile source of ignition failures.

**The Spark Plug.**—Formerly, nearly all ignition troubles were attributed to poor spark plugs. Now, we understand that such troubles arise from many other sources. Nevertheless, a spark plug is a delicate instrument, and one frequently deranged.

The commonest source of trouble is short-circuiting, due:

1. To breaking down of insulation, cracking in porcelain plugs, oil-soaking, deterioration of cement filling, or metallic impurities in mica plugs.

2. To fouling with soot between the electrode surfaces and spark points.

Troubles due to the first cause demand renewal of the plug. Fouling with soot may generally be removed with gasoline.

Preventives of fouling are:

1. An annular space between the core insulation and the outer shell, producing a vortex, as is alleged, and allowing piston suction to remove deposits.

2. An outside spark gap, which will generally suffice to insure a a spark, but it does not prevent fouling between the spark points.

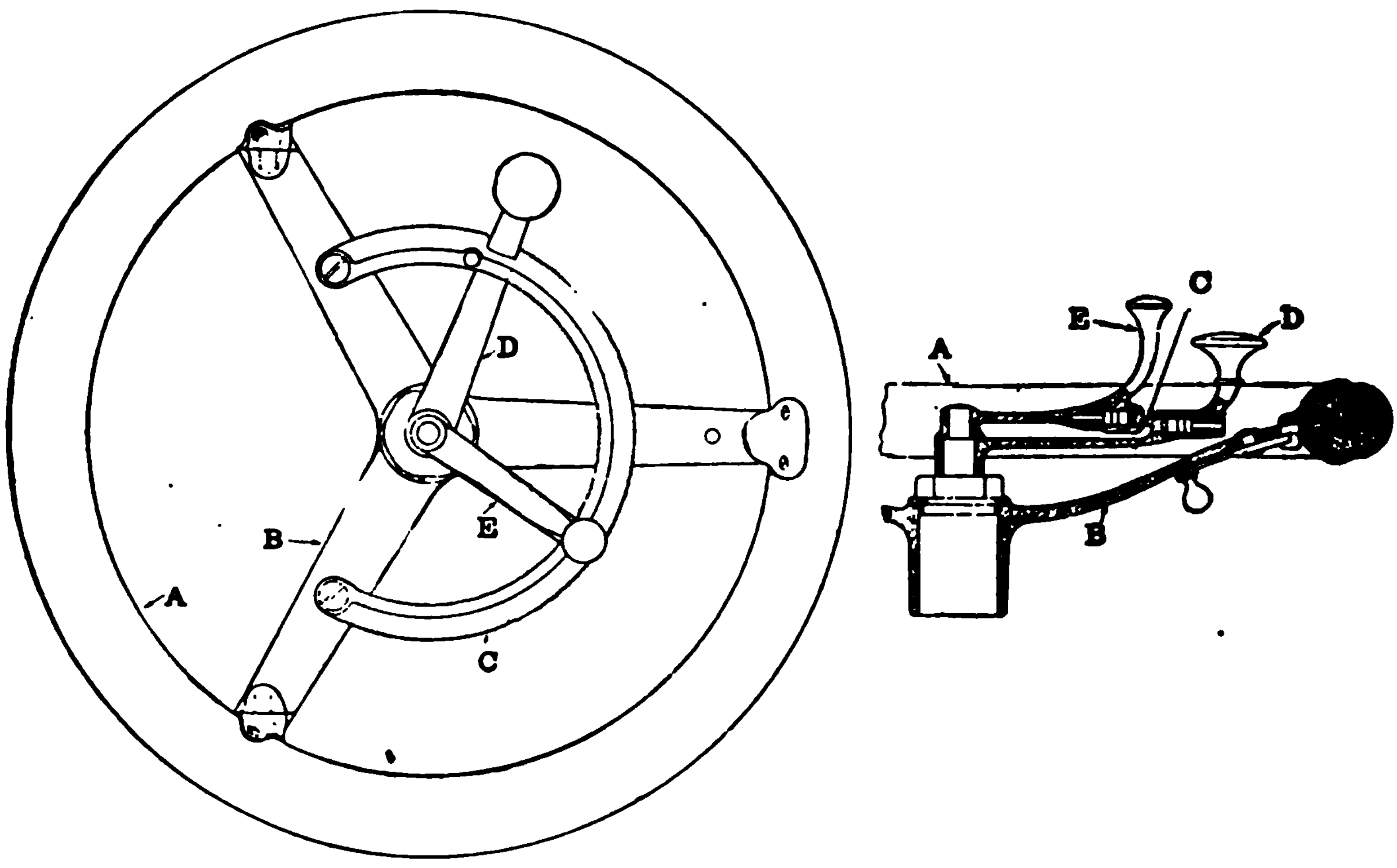



FIG. 231.—Steering Wheel and Attachments of the Pope-Toledo Carriage. A is the wheel rim; B, a spoke or arm of the three-armed spider; C, sector for sliding arms, D and E; D, throttling arm and handle; E, spark regulating handle. The throttle is opened by moving the handle clockwise around the sector; the spark is advanced by moving its handle in the same direction.

**Circuit Wiring.**—The principal points for examination are:

1. The terminals and binding posts.

These should be firmly secured—all looseness being avoided—although crushing of the wires should be carefully guarded against.

2. The insulation which should be examined for breaks, flaws or rubbed areas. By this means leaks and short circuits will be avoided.

**Preparing to Start the Engine.**—In preparing to start the engine of a gasoline motor carriage, it is necessary to be careful:

1. That the clutch is thrown out, so that the vehicle cannot start until desired.

2. That all parts of the lubricating system are in working order, all connections opened, and the supply of oil sufficient. Be sure that all sight-feeds are supplying regularly.

3. That both gasoline and water tanks contain sufficient liquid for the contemplated run.

It is an excellent plan to test both tanks on each occasion of preparing for a run. Some motor carriages have glass gauge tubes fixed to the fuel and water tanks, so that the level of the liquids may be determined at a glance. In others it is a simple matter to test the level by inserting a stick in the filling hole and noting the height to which the liquid rises on it. This may be done with gasoline if the stick is withdrawn quickly and examined before evaporation takes place.

4. That the sparking circuit is closed, which involves examination of all switches, to insure certainty that they are on the "closed" point.

5. That the lever on the spark control quadrant stands at the extreme "back" position, retarding the spark to the limit.

To neglect this may cause "back-kick" at cranking, as will be explained later.

6. That the carburetter control lever is moved to the "open" position, for ensuring the *richest* mixture under operating conditions, in order that, even with the low suction at starting sufficient power may be obtained for a good headway.

A rich mixture may occasionally fail to ignite at starting, but a weak mixture is more often at fault.

*Except at starting,* however, the *open* throttle and *late* spark should never occur at the same time. Apart from involving a waste of energy, it is liable to occasion injuries to the engine, as specified later.

7. That the cock on the tube between fuel tank and carburetter is opened.

This is, of course, a positive necessity, since, with only the gasoline standing in the float chamber, the engine will operate for only a few strokes, if at all. It is a vexatious thing to find that the engine will not respond to cranking, but this is a trouble that may be readily forestalled, provided no actual derangements exist.

8. That the carburetter is in proper working order.

It may occasionally happen, particularly after standing for a long period, that the valve of the carburetter sticks. This will interfere, of course, with proper feed of fuel. To determine whether all parts are in good condition, it is desirable to *flush* or *prime* the carburetter by depressing the protruding end of the valve spindle or the *flusher*. This act depresses the float, opens the valve, allowing liquid to enter the chamber, and thus proves that there is no clog or interference.

Under conditions of operation it is extremely bad to allow the carburetter to flood. However, at starting, it is often a means of ensuring sufficient richness of mixture to enable ignition to take place.

**Water in the Carburetter** will often prevent starting of the engine, and will always impair its efficiency. Water is very frequently present in gasoline, and, particularly when the tank is low, is liable to get into the pipes and carburetter. Every carburetter has a drain cock at the bottom to let off the water that settles from the gasoline.

The natural result of water in the carburetter is impaired or interrupted vaporization of gasoline.

In cold weather, also, the water is liable to freeze, preventing the action of the carburetter parts and clogging the valves. Ice in the carburetter can be melted only by the application of hot water, or some other non-flaming heat, to the outside of the float chamber.

It is not at all necessary to drain the carburetter before every starting, but after a prolonged period of inactivity it is desirable to give the water an opportunity to escape.

A strong presumption of water in the carburetter is established when the engine starts, runs fitfully, or irregularly, and finally stops.

**Stale or Low-Degree Gasoline.**—Another condition that will produce some of the same symptoms is low grade or stale gasoline. These two varieties of spirit are practically identical, in effect at least, both being characterized by a lower specific gravity than is required for readily forming a fuel mixture. Gasoline, or petrol spirit, as it is called in England, should have a specific gravity of about .682, or 76°B. Some English authorities recommend spirit having a specific gravity of from .72 to .74, or between 65° and 59°B, virtually what is known in the United States as high-grade benzine. Hydrocarbon spirits of lower degrees on the Baumé scale become increasingly difficult to vaporize.

Gasoline, being a volatile essence distilled from petroleum oil at temperatures ranging between 122° and 257°F., and boiling at between 149° and 194°, on the average, is a compound of several spirits of varying density, gravity and volatility. Chemically, it is represented by formulæ ranging from $C_5H_{12}$ to $C_7H_{16}$, with the average $C_6H_{14}$. It follows, therefore, that, unless stored in an air-tight vessel, the lighter constituents are liable to escape, leaving a residue that will show a registry on the Baumé scale below that found easiest to vaporize.

This is the process that occurs in the carburetter, if gasoline is allowed to stand in it for any length of time. It is always best, therefore, on storing a vehicle for a protracted period, or, in the event of failure to start the engine, after such extended inactivity, to drain the carburetter.

Of course, if the tank is found to contain only low-degree liquid, the only alternative is to empty it and refill with a supply of the proper quality.

**Cranking the Engine.**—All preliminary conditions having been carefully observed, the engine is in readiness to start. With all cocks open, the electric circuit closed, the spark retarded, the mixer properly adjusted, it remains only to crank the engine. Under favorable conditions, it is necessary to *turn the engine over,* as the term is, but once, or to put it through the aspirating and compression strokes, to the point of ignition. It will then *take up the cycle* and run without further assistance.

When all adjustments are perfect, the engine should start within two revolutions after the first turn of the starting crank. The necessity for long-continued and vexatious turning of the crank certainly indicates trouble, as will be explained later.

If, on the last run, the engine was stopped by interrupting the sparking circuit, rather than by cutting off the fuel supply, the probabilities are that, under good conditions, a single lift on the crank will be sufficient to start, by bringing the fuel in cylinder to the sparking point.

**Defective Fuel Mixture.**—It frequently happens that too *rich* a mixture will not ignite readily on cranking, and, as a consequence, the engine will not start. It is necessary, then, to reduce the mixture, allowing more air to enter the carburetting chamber.

*If the engine starts* with a rich mixture, the result is liable to be seen in a heavy and ill-smelling smoke from the muffler. The color of this smoke will determine the nature of the trouble.

*Dark-colored dense smoke* indicates an excess of gasoline in the mixture, and may result from one of the following conditions:

1. A very rich mixture.
2. Imperfect combustion.
3. Defective ignition.
4. Either excessive or defective lubrication.
5. Overheating and consequent flashing of the lubricating oil.
6. A leaky piston.

The two most usual causes of dark smoky exhaust, however, are:

1. Defective carburetter action, due probably to grit under the inlet needle valve, or else to some derangement of the parts.

2. An over-rich mixture, which ignites imperfectly.

*White dense smoke* indicates an excess of oil or a resulting deposit of carbon soot in the cylinder, or a poor oil that is liable to flash at low temperatures.

*Thin blue,* or nearly invisible smoke indicates a normal mixture and good ignition.

*An unpleasant odor* in the exhaust is frequently mentioned as the one necessary evil of motor carriage operation. It is certainly nothing of the sort, and most often indicates poor lubricating oil or too rich a mixture, which involves wasteful use of fuel. A

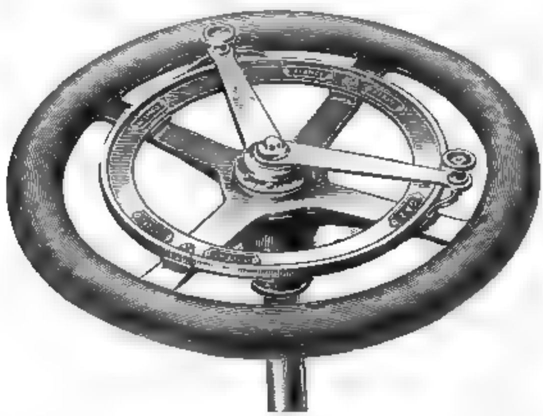


FIG. 232—Steering Wheel and Control Levers of the Vinot Motor Carriage. The throttle and spark levers work on opposite arcs of the ring. Both turn clockwise for high speed adjustments, and counter clockwise for low speeds, as indicated.

good mixture, perfectly ignited, in a cylinder lubricated with high test oil, should have no very bad odor.

*Bad odors and smoke at starting* are frequently produced by chemical conditions other than a poor oil or an over-rich mixture. They are also common when running at slow speeds. Long continued, however, they constitute a nuisance that demands earnest and careful attention.

**Reducing Smoke in the Exhaust.**—Smoke from the exhaust being a sure indication of oil-flooding or too much gasoline in

the fuel mixture, demands attention to the *oil feed* and *carburetter,* as follows:

1. Reduce rate of oil feed, if the smoke indicates oil. If this is the sole trouble, the smoke will decrease after a few revolutions of the fly-wheel.

2. Restore the oil feed nearly to normal and adjust the carburetter.

3. Examine the air inlet of the carburetter, and cleanse the gauze screen of any dust. This will restore the air supply.

**Dangers of a Smoky Exhaust.**—A smoky exhaust, indicating the presence of excess oil or carbon deposits in the cylinder, should serve as a warning in one respect. The soot formed is

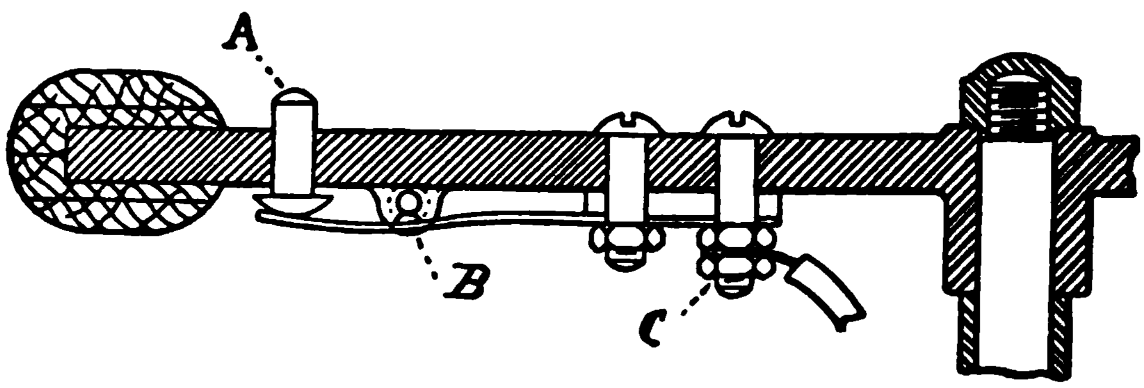



FIG. 233.—The Searchmont Steering Wheel with Electric Circuit Breaker. One terminal is at C, the other at pin, B. By depressing button, A, contact may be broken. By withdrawing pin, B, circuit may be interrupted, rendering it impossible to start the engine.

liable to take fire and smolder, causing pre-ignition, even backfiring, particularly under heavy loads. If, after other relief measures have been tried, the nuisance persists, the cylinder interior should be cleaned at the earliest opportunity. This, of course, cannot be done until the engine is brought home and can be dismantled at leisure. To forestall further mishaps, continue the journey with as weak a mixture as possible.

In cold weather considerable watery vapor appears in the exhaust.

**Cleaning the Cylinder.**—The interior of the cylinder may be cleansed by injecting a moderate quantity of gasoline, kerosene, or other solvent, through the spark-plug hole or compression tap, and turning the engine over with the starting crank, causing the piston to make the sweep from end to end several times, thus enabling the solvent liquid to cut the obstructing deposits. Some

English authorities, notably Mervyn O'Gorman, discourage the use of gasoline, on the ground that it evaporates too quickly to be of use in this manner, and advocate the injection of small doses of kerosene. O'Gorman states that, in moderate quantities, kerosene will not form hard carbon deposits, as some assert.

It is an excellent plan to thoroughly clean the interior of the engine at regular intervals, depending in length upon its use. This involves disconnecting the cranks and removing the pistons. The interior of each cylinder may then be wiped out with cotton rags or cotton waste—preferably the former—dampened with gasoline or kerosene. Care must be taken to leave no threads within the cylinder. By this method all soot and gum deposits

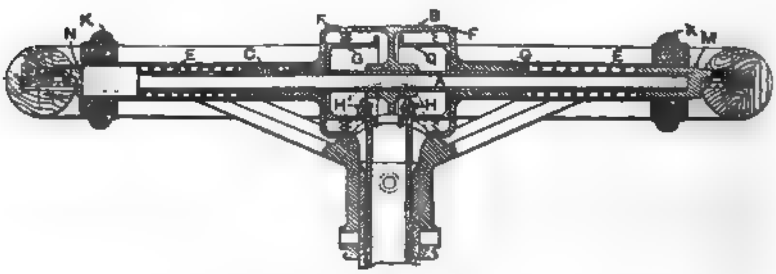



FIG. 231.—Steering Wheel and Attachments of the Panhard-Levassor Carriage. A, a shaft on a diameter of the wheel; B, a cylindrical fixed cap with toothed end; C, C, a sleeve with toothed ends, F, F, in normal engagement with B, under tension of springs, E, E, being prevented from rotating; G, G, drums on which wire cables, H, H, are secured and wound; K, K, knurled handles which may be grasped and pulled against the springs, allowing rotation of G, G. One cable, H, leads to carburetter link, the other to the spark adjuster.

may be effectually removed, and the piston may be cleansed of gummy deposits under its rings. On completing the operation, the parts should be oiled sufficiently to render their mutual movement easy. Hard carbon deposits may be removed with a table knife.

**Causes of Defective Mixtures.**—An over-rich mixture—one containing an excess of gasoline vapor—may be caused by any one of several conditions, prominent among which are:

1. An air inlet clogged with dust or ice on the gauze.

2. A piece of grit or other object preventing closure of the needle valve.

3. A leaky float, which has become partially filled with liquid gasoline, and is, therefore, imperfectly buoyant.

A leaky float may be repaired by soldering, but authorities recommend that, in this work, a vent be made at some convenient point, and the float cooled by setting on a cake of ice, after which the vent is soldered up, leaving the air within at atmospheric pressure.

A poor mixture may be caused by:

1. An excess of air drawn through some leak in the air pipe.

2. Water in the gasoline.

3. A feed pipe or feed nozzle clogged with lint, grit or other obstructions.

The quality of the mixture may generally be determined from the effects on the operation of the engine. If it is not obvious in this manner, it may be determined by actual test. Charles E. Duryea recommends the following procedure:

"It is usually possible to form an idea of the trouble by opening the peep cap of the cylinder [if one is provided, as on the Duryea engine], or removing the plug and applying a lighted match. If the mixture is too rich, it will burn yellow; if too poor, it may not burn at all or faintly blue; but if just right, it will explode and rush out of the opening to the danger of one's fingers. If it seems to be poor, injecting a little gasoline from a squirt can, or flooding the carburetter, will prove whether or not the diagnosis is correct, and, having determined what is the trouble, the cause may usually be found."

**Preparing to Start in Winter Time.**—As a rule motor carriage engines work indifferently in cold weather, and for this reason are little used in the winter months. A low temperature interferes with effective engine working in several ways:

1. It renders difficult a rapid vaporization of the fuel.

2. It causes the lubricating oil to thicken, and in some cases to become gummy.

3. It causes freezing of the jacket water, unless precautions are taken to prevent it.

**Carburetting in Cold Weather.**—The uncertainty regarding good vaporization is the principal source of failure to operate in Winter time, and furnishes an argument in favor of hot air feed, as in the Centaure carburetter, or hot water jacket for the vaporizing chamber, as in the Krebs. It is obviously impracticable to heat the ordinary variety of sprayer, except by arranging the air feed pipe to run over or around the muffler, which would doubtless assist matters considerably after the engine is started. The hot exhaust gases are used by several designers.

**Sticking from Gummed Oil.**—In cold weather, or after the engine has been inactive for a considerable period, the oil in the cylinder is likely to be thickened, with the result that it is unusually difficult to turn the crank. If a few turns with the electric switch open, do not suffice to loosen the adhesion by friction, the result may be accomplished by squirting a small quantity of gasoline over the piston with a syringe.

**Freezing of the Jacket Water.**—Nearly the most fatal form of carelessness in the management of a gasoline engine is to allow the cooling water to freeze in the jackets. A frozen water jacket generally bursts without, however, doing certain injury to the arched walls of the cylinder. The engine may be started, therefore, but soon heats up, the jacket water leaking out through the breaks. The heat will burst the jacket which withstands the ice.

**Precautions to Prevent Freezing.**—In cold weather a careful motor-carriage driver will drain all water from the jackets and circulating system by opening all pet cocks on the cylinder jacket, the pump and feed tubes and the radiator. After the water has entirely run out, the jackets and tubes may be dried by allowing the engine to run for not over a minute, thus vaporizing and expelling all remaining moisture.

**Non-freezing Jacket Solutions.**—When a motor vehicle is to be run in winter weather, particularly if it is to be left standing with the engine not operating, some kind of non-freezing water solution is highly desirable. Such a solution is one that lowers

the freezing point of the water, allowing it to remain liquid even below 32°F. (0°C.) There are several such in use, all recommended by authorities:

1. A solution of water and glycerine: water 70% by weight; glycerine 25% to 30% by weight; sodium carbonate ($Na_2 C O_3$), or "washing soda," 2% by weight.

The glycerine is liable to congeal at very low temperatures, but this tendency is largely neutralized by the presence of the soda. With this solution the contents of the jacket and radiator had best be drawn off, and renewed at least once a month.

2. A solution of water and calcium chloride ($Ca Cl_2$), in proportions of 10 lbs. calcium chloride, dissolved in a pailful of boiling water, forming a saturated solution. Allow the mixture to boil, and then to settle. Test with litmus paper for acid, which may be neutralized with quicklime. Test occasionally for acid formed by heat.

Before pouring this solution into the tank, it should be carefully strained through a fine cloth, to remove all sediment.

Only the *chemically pure* calcium chloride ($Ca Cl_2$), sold by responsible chemists, should be used for this solution, and one should carefully avoid using the so-called "chloride of lime," commonly known as calcium hypochlorite ($Ca Cl_2 O_2$).

3. A solution of equal parts by weight of water and wood alcohol.

4. A solution of two parts wood alcohol, 1 part glycerine, 1 part water, is also recommended by Roberts.

**Draining the Jackets.**—Although any one of the solutions given above prevent freezing of the jacket water, many users find it more satisfactory to drain the jackets through the pet cock on the radiator, when the car is to stand over night, and refill before the next start of the motor. This practice is preferable because the solutions are toublesome and dirty, and at best, do not cool as well as pure water.

**Back-kick and Back-firing.**—A form of disordered action, sometimes encountered on starting the engine, and most often due to non-observance of necessary rules, as already laid down, for adjusting the engine and auxiliary parts, is known as back-firing. This means that the ignition of the charge takes place at such a point in the cycle that the motion of the engine is reversed. Back-firing is often known as pre-ignition.

If back-firing occurs while the operator is holding the crank, it produces a back-kick, which is liable to dislocate his shoulder, unless the crank throws off automatically.

The term *back-firing* is also applied to an explosion occurring during or at the end of the inlet stroke, when the gas in the carburetter mixing chamber is ignited. This is due generally to a loose or defective inlet valve, a pitted inlet valve seat, smoldering carbon residue in the cylinder space, or a spark due to a disarranged ignition circuit. The logical presumption is that the inlet valve needs grinding in its seat, in the same manner as is subsequently explained in connection with the exhaust valve.

*Back-firing,* or ignition at the wrong point in the cycle, with reversed piston movement, must be carefully discriminated from *after-firing,* or explosion in the muffler or exhaust pipe. Occasionally the same term is erroneously applied to both mishaps.

**Causes of Back-firing.**—Back-firing, or pre-ignition, may occur under several conditions. Prominent among these are:

1. An early ignition, at or before the backward dead-centre of the crank, before the cycle is established, as in the act of cranking the engine for a start. The result is then a *back-kick,* as already explained. This can only emphasize the necessity of retarding the spark at starting, so that it will not occur until the dead-centre is fairly passed over, and the piston has begun the out-stroke.

2. Overheating of the cylinder walls, due to insufficient heat radiation (in an air-cooled engine) or too little jacket-water (in a water-cooled engine). This should emphasize the necessity of keeping the water supply sufficient for all needs, and of assur-

ing the perfect operation of the circulation system, pump, radiator, etc., before starting the engine.

3. Soot deposits within the combustion space, due to carbonization of excess oil, etc. Such deposits will readily ignite and smolder, and will thus furnish an almost certain source of ignition, during the compression stroke.

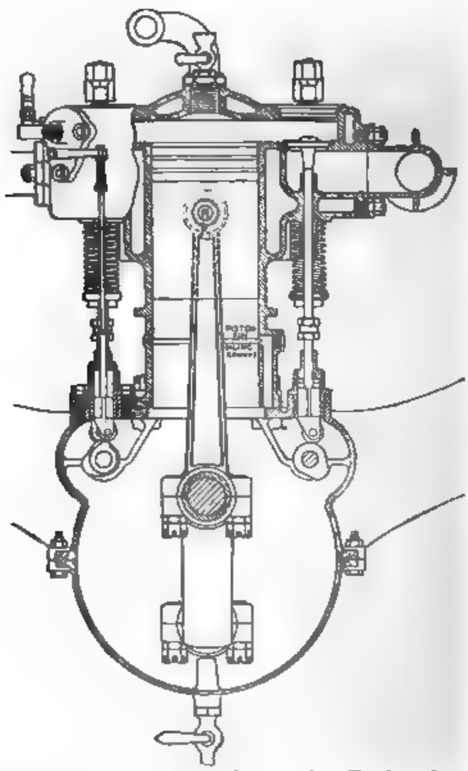


FIG. 235.—Section Through a Cylinder of a Gasoline Engine, showing arrangement for operating inlet and exhaust valves from two separate cam-shafts. This engine is ignited by a primary sparker, operated by a separate cam on the inlet cam shaft.

4. By an attempt to increase the power-output of the engine, when operating under a heavy load, as in ascending a steep grade, etc., by advancing the spark too far. In this case the conditions causing back-kick at starting are closely approximated. In this case the engine is running too slow for an early spark.

**Preparing to Start the Vehicle.**—Before starting the vehicle by throwing in the clutch, it is necessary to bring the engine to running conditions. In starting the engine, the throttle is opened wide and the spark retarded because of:

1. The weak suction of the piston at slow speeds.

2. The need of ensuring a mixture that will ignite under such conditions.

3. The impossibility of using an early spark, as has already been explained.

With a late spark and the throttle barely open, the engines will run, giving little or no power.

**Changing the Spark and Throttle Adjustments.**—When the engine has speeded up, the adjustments must be changed:

1. The spark must be advanced.

2. The throttle must be partially closed.

If there is a mechanical governor on the engine, the throttle will be shut down automatically, as the engine speeds up.

**Reason for Adjustments of Spark and Throttle.**—It is necessary to adjust, as just specified, because *the engine should never be allowed to run with an open throttle and a retarded spark.*

This rule is imperative for two reasons:

1. The spark being late, the expansion of the gas has progressed only very slightly at opening of the exhaust: whence a large percentage of power is thrown away.

2. More important still, the intense heat thus generated is liable to injure, if not burn away, the spindle of the exhaust valve, when the condition is long continued.

**Racing the Engine.**—On the other hand, it is undesirable to allow the engine to attain an excessive speed previous to throwing in the clutch. No good is attained, since:

1. It is undesirable, if not dangerous, to throw in the clutch with the engine running at high speed.

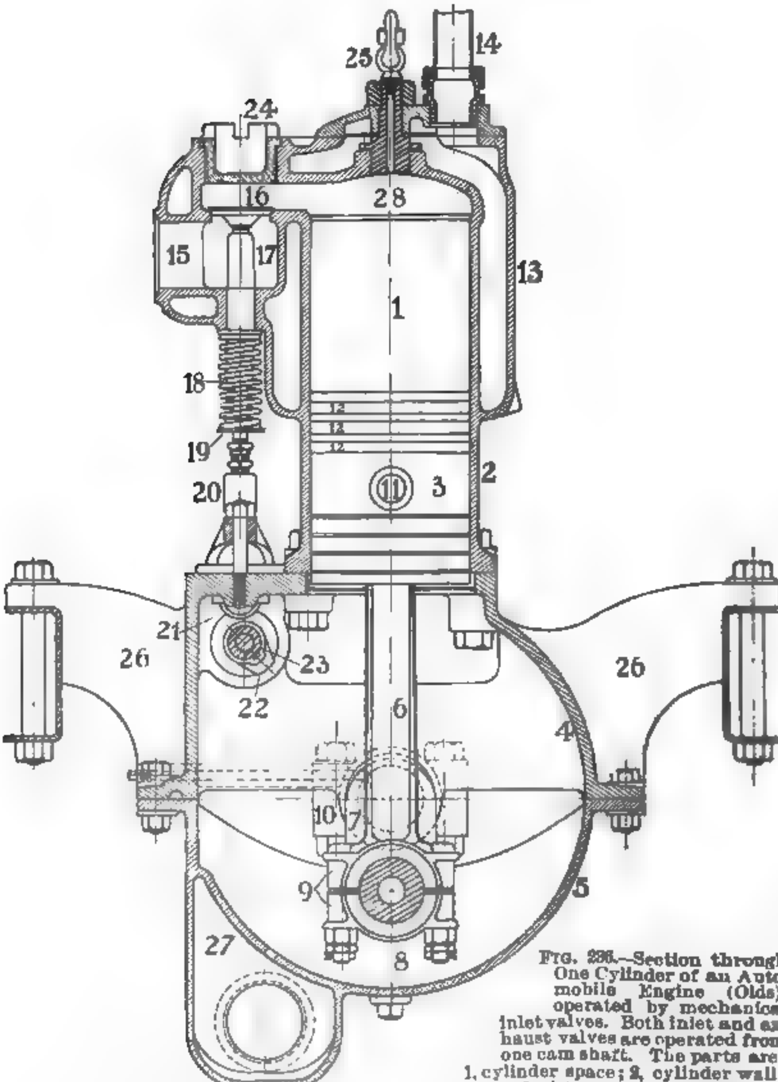



FIG. 236.—Section through One Cylinder of an Automobile Engine (Olds), operated by mechanical inlet valves. Both inlet and exhaust valves are operated from one cam shaft. The parts are: 1, cylinder space; 2, cylinder wall; 3, trunk piston; 4, crank case, upper half; 5, crank case, lower half; 6, connecting rod; 7, crank shaft brasses; 8, crank pin; 9, crank pin brasses; 10, crank shaft bearing; 11, piston pin; 12, 12, 12, piston packing rings; 13, water jacket; 14, water outlet pipe; 15, exhaust valve outlet; 16, exhaust valve; 17, exhaust valve chamber; 18, valve spring; 19, valve spring retainer; 20, valve push rod guide; 21, exhaust cam roller; 22, exhaust cam; 23, exhaust cam shaft; 24, valve chamber cap; 25, relief cock; 26, 26, engine brackets or hangers; 27, oil circulating chamber; 28, combustion space, or clearance.

2. There is great danger of loosening and straining connections, nuts and bearings, since there is always more vibration when running free than when under load.

**Retarding the Spark.**—It is imperative that the mixture be throttled before the spark is retarded, for the reasons just given.

**Advancing the Spark.**—In advancing the spark, the sparking handle should be manipulated *first;* afterward, the throttle handle. The reason for this is the same. *Never, except at starting,* let the spark handle stand behind the throttle.

**Failure to Start.**—Refusal of the engine to take up the cycle, even after prolonged cranking, is a familiar experience in motor vehicle operation. Unless some accident has occurred, or a very unusual strain has been thrown upon the working parts, the inference is that some element of the rather complicated group of apparatus is out of adjustment.

**Causes of Failure to Start.**—If all preliminaries, hitherto specified, have been carefully observed, and the engine shows good compression at cranking, the probable causes of trouble should be sought:

1. In the sparking plug.

The spark-points may be too far apart; there may be fouling between them; the plug may be short-circuited, or the insulating layer of porcelain or mica may be broken down.

2. In the carburetter.

The spray nozzle may be clogged; there may be water in the float chamber; low grade gasoline may be used; too much or too little air may be admitted. The supposed carburetter trouble may be located in the fuel tank or supply pipe; in the throttle or may be due merely to faulty valves.

3. In the battery.

The battery may be run down or polarized.

4. In the circuit wiring or connections.

There may be a short-circuit, due to a broken wire or defective insulation, or there may be a looseness at some binding-post.

5. In the vibrator of the coil.

There may be a defective adjustment of the vibrator, preventing it from responding to the strength of current in use, or the vibrator may be broken loose.

6. In the interior of the coil, as previously explained.

**Fouling of the Spark Plug.**—Persistent failure to start, when buzzing of the induction coil vibrator indicates that the electric circuit is in working order, may be attributed to fouling of the

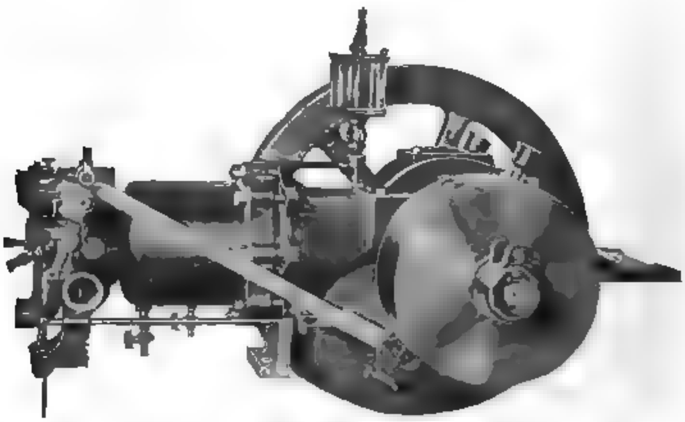


FIG. 287.—The Cadillac One-Cylinder Engine, showing connections for operating the valves and speed gear on the main shaft. The inlet valve is positively operated by a bell crank worked from a pushrod from the second shaft; the exhaust valve, by a walking beam, from an eccentric, also on the second shaft.

spark plug. Fouling may consist of liquid oil or soot. Both give most trouble at starting.

Fouling may be removed:

1. By using a well-made spark-gap arrangement.

2. By a temporary spark-gap, made by disconnecting the lead wire of the plug and holding its end at a sufficient distance to allow a visible spark to leap from it to the plug core.

If this proves ineffective, the plug should be unscrewed and examined. Any visible fouling may then be removed by rubbing

the insulation with fine emery paper until the bright surface of the porcelain is visible, taking care not to impair the surface.

**Testing the Spark Plug.**—If no fouling appears, the plug may be laid upon the cylinder or frame so that its case only is in contact, and thus grounded, and on cranking the engine, the spark may be seen leaping between the points.

If a spark does not appear, it is probable that, with the ignition circuit in working order, there is some breakage or short circuit in the body of the plug. This, of course, necessitates its removal and the substitution of a new one. If a spark appears, the search for trouble must be continued to other apparatus.

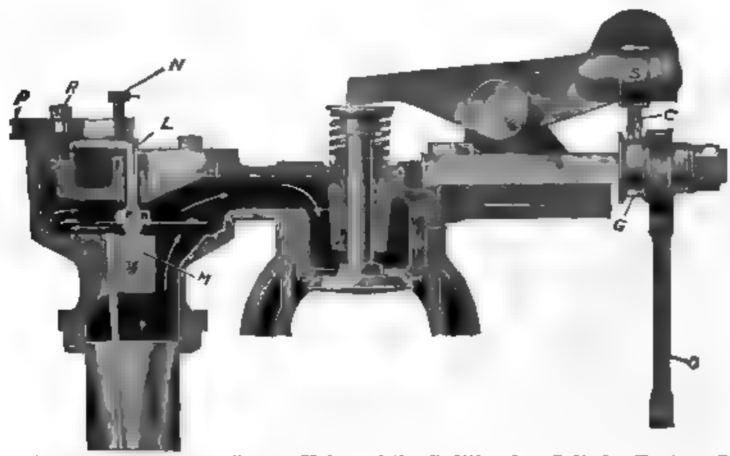



FIG. 238.—Carburetter and Intake Valve of the Cadillac One-Cylinder Engine. L is the gasoline valve; M, gasoline inlet; N, adjusting screw. A, inlet valve; T, walking-beam for opening it under positive impulse; C, end of eccentric rod, raising T by bearing on roller, S, with roller, G, as fulcrum. O is the handle by which the position of G, consequently the lift of the valve, A, may be varied as desired.

**The Spark Points of a Plug.**—Very frequently a perfectly sound plug will fail to spark, simply because the spark points, for some reason or other, have been too greatly separated, or else because the battery is nearly exhausted. In either case the trouble may be overcome by bringing the spark points nearer. For average strength of battery, the distance between the points should be about 1/32 inch, and practically never more than 1/16 inch.

**Failures with Four Cylinders.**—Unless the ignition circuit is elsewhere disarranged—in battery, coil or wiring—failure to start in a four-cylinder engine is probably due to causes other than foul or defective spark plugs. It may happen, however, that one, or even two, of the cylinders will fail to ignite. This condition will show symptoms similar to those caused by misfiring, irregular movement and vibration.

**Testing for the Missing Cylinder.**—In practically all four-cylinder engines made at the present day the cranks of the second and third cylinders are in line, and are set at 180° to the cranks of the first and fourth, which are also in one line. Consequently, the pistons of the second and third cylinders make their instrokes at the same time as the first and fourth make their outstrokes. As a rule, the order of ignition is: first, third, fourth, second, which is also the order in which the primary circuit is closed at the commutator through the primary winding of each coil in succession.

In order, therefore, to determine which cylinder, if any, is missing fire, it is necessary only to open the throttle and advance the spark lever to the running position, giving the engine good power, and to cut out three of the four cylinders by depressing their coil vibrators. If the engine continues to run with coils 2, 3 and 4 cut out, cylinder 1 is evidently working properly. Depressing vibrators of 1, 3 and 4 shows whether 2 is working; of 1, 2 and 4, whether 3 is working, and of 1, 2 and 3, whether 4 is working. On discovering the faulty cylinder, its plug may be tested precisely as is the plug of a single-cylinder engine.

A precisely similar process may be followed in the search for a missing cylinder of a three or six-cylinder engine.

A missing cylinder may also be found by the low temperature of its exhaust pipe, provided the missing be long continued.

**Misfiring During Operation.**—Occasionally, the missing of one or more of the cylinders will be noticed during the operation of the engine. This trouble may be recognized by irregularity of motion, gradual slowing down, and, generally, by *after-firing*,

or explosions in the muffler. If, by the coil-cut-out test, just described, it be found that one particular cylinder is at fault, it is fairly probable that a faulty spark plug, a loose wire in the secondary circuit, or a sticking valve is the cause.

If the trouble cannot be thus located in one of the cylinders the inference holds; either that there is some general derangement of the ignition circuit, or that the fuel mixture is not right.

**Misfiring: Short Circuits.**—Very frequently misfiring is caused by a short circuit, which is to say a ground, or an arcing gap between the two sides of the secondary circuit, at some point short of the plug terminals. This will, of course, prevent

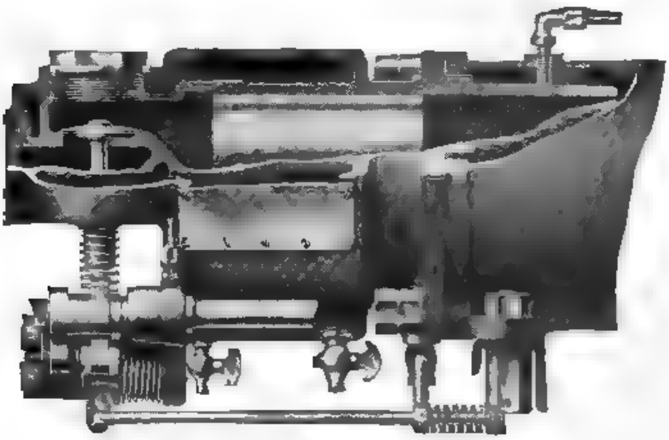


FIG. 239.—Part Sectional View of the Olds Motor, showing valve-operating mechanism. The cam-shaft, extending horizontally to the head of the motor, actuates a rocking cam, which in turn pushes both the inlet and exhaust valve stems, projecting below the motor head. The cam shaft is rotated by a helical gear from the main shaft of the engine.

sparking at the plug, although, owing to the vibration of operation in the other cylinders, the short circuit may occasionally be interrupted and the spark will occur.

Such a short circuit differs from an *extra spark gap,* in that the latter is *in series* with the plug gap, while the former gives a leak *in parallel* to it.

*A broken-down coil,* or one in which the insulation is weakened, allowing internal leaks and sparking, will cause misfiring for a time, and will very soon be of no use whatever.

**Misfiring: Loose Connections.**—Loose connections of the wires at a binding screw, in either primary or secondary circuit, may cause misfiring, or irregular firing, in very similar fashion. The looseness may be small, or it may be excessive, and the condition in this respect determines the degree of interference in engine operation. Thus, a loose connection may allow the engine to run from rest to a moderately good speed before trouble begins, or the vibration of operation may interrupt the contact entirely. This only emphasizes the necessity of keeping connections tight. Spring connections are much used now.

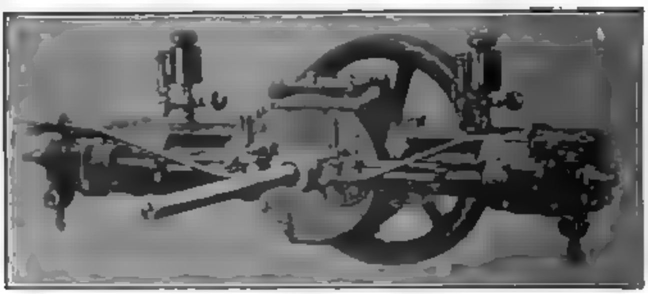


FIG. 241.—Double Opposed Horizontal Cylinder Motor of the Haynes-Apperson Carriages. The two cylinders of this motor are somewhat offset, as shown in the cut, the crank rods working on two cranks. The long crank shaft shown at the front of the engine is for carrying the individual clutch change speed gear. The reciprocating parts are lubricated by adjustable oil feed cups shown at the top of each cylinder. Ignition is by break contact spark, the exhaust connections being on the same plan as those described for other motors. The inlet valves are operated by suction, and are at right angles to the positively operated exhausts.

**Misfiring: Weak Battery.**—As we have already learned, a weak battery may prevent sparking between the plug points, and can be remedied in no better fashion—provided no extra battery be at hand—than by reducing the gap between the points. As a consequence, a weak battery is a frequent cause of misfiring.

Misfiring due to a weak battery may be diagnosed by the occasional apparent violence of the explosions, on account of frequent misses. A weak battery will cause misfiring most conspicuously when the engine has been run up nearly to full speed, and then suddenly drops, owing to irregular ignitions. The reason is, obviously, that the weak battery cannot supply good fat sparks at a

rate commensurate with the requirements of rapid operation. With a reduced spark gap and a slow speed, it may be able to enable operation for a limited period.

These principles apply, of course, to chemical batteries. When the current is obtained from a magneto or dynamo, the trouble—if traced to the source—is probably due to loose or worn brushes, a glazed commutator, or a short circuit somewhere in the armature, or around the brush holders.

**Misfiring at High Speeds.**—Among other causes of misfiring at high speeds may be mentioned a faulty adjustment of the coil vibrator, giving extremely short *makes* of the primary circuit and slow rates of vibration, which cannot keep pace to the requirements of high engine speeds.

Loose circuit connections, shaken out of position as the engine speeds up, and weakened batteries are far more common causes of this mishap at high speeds, as already indicated.

**Misfiring: Defective Mixture.**—A defective mixture will frequently occasion misfiring, on account of difficulty of igniting. Such a defective mixture may be one that is either too rich or too weak, and may be produced by a flooded carburetter, or one in which sticking, or some similar disorder, prevents the feeding of sufficient gasoline spray for a good mixture.

In either case the ignition of the charge is slow, if it occurs at all, and the result is that unburned gas is discharged into the muffler, producing after-firing and reducing the power efficiency.

**After-Firing in the Muffler.**—After-firing, or "barking," sometimes incorrectly called back-firing, and consisting of a series of violent explosions in the muffler, is commonly caused by misfires in one or more cylinders, permitting the accumulation of unburned gas in the muffler, which is ignited by heat of the walls or by the exhaust of firing cylinders. Sometimes it may be due to a mixture that is too rich or too weak, and hence burns slowly, continuing its combustion after passing into the exhaust. It also occurs, not infrequently, when the spark is retarded to slow the

engine before stopping. No particular harm results from this rather startling effect, since the explosion can seldom occur until the unburned gas comes into contact with the outer air.

**Running Down.**—When the engine starts well, runs for a while, then slows down and stops, there are very many conditions to which it may commonly be attributed. Among these are:

1. Water or sediment in the carburetter.

2. Loose connections, break-downs, or any other disarrangement of the ignition, such as would otherwise interfere with starting.

3. A weak or imperfectly recuperated battery—frequently the latter—that suddenly fails to supply current.

4. A leak in the water jacket that admits water to the combustion space.

5. Seizing of the piston in the cylinder on account of failure of the cooling system. This may result, in a water-cooled cylinder, from:

*a.* Exhaustion of the water.

*b.* Stoppage in the pipes or pump.

*c.* Breakdown of the pump.

*d.* Failure of the oil supply.

In an air-cooled cylinder seizing may result from:

*a.* Insufficient radiation surface.

*b.* Obstructed air circulation.

6. Heated bearings that seize and interfere with operation.

7. Poorly matched or poorly adjusted new parts, particularly pistons, that cause heating and perhaps seizing from friction.

8. Lost compression from broken or stuck valves, leaky piston, etc., as explained in the succeeding paragraph.

**Low-Compression Troubles.**—Practically all the mishaps hitherto mentioned may occur with a good compression, which may be recognized on turning the starting crank. When little

or no compression manifests itself as a resistance to the turning of the crank, it is certain that the operation of the engine will be defective, provided it can be started at all. If the engine loses compression after it has started, it will misfire and slow down.

Low compression means absence of a sufficient quantity of gas mixture to give a good power effect. This absence results from a leak in the combustion chamber, due to:

1. A sticking inlet valve—if the inlet be automatic—from an incrustation of oil gum. Sticking may be due to other causes also.

2. A pitted or corroded exhaust valve.

3. A weak spring on the exhaust valve.

4. A loose or open compression tap.

5. A leaky piston, due to:

*a.* Worn or broken piston rings.

*b.* Piston rings worked around, so as to bring the openings on their circumferences into line.

6. A blown-out gasket in the cylinder head.

7. A worn or loose thread at the insertion of the spark plug.

8. A broken valve or valve stem.

9. Worn or scratched sweep wall, due to lack of oil or the presence of grit.

10. A valve-stem that is so long as to touch the end of the pushrod when the engine is cold. The remedy for this is to file the end of the valve stem until a card may be inserted between its end and the end of the pushrod.

**Regrinding of Valves.**—Whenever the cause of low compression is found to be a pitted or corroded exhaust valve seat, which permits leakage, the process of regrinding, or "grinding-in," as some call it, must be the resort. Briefly described, this process consists in rotating the valve on its seat, until the seat is made perfectly smooth by an abrasive substance smeared on the level

of the valve. In regrinding the exhaust valve, the inlet valve casings—if an automatic valve is used—is removed from the valve chamber. The exhaust valve spring is removed from its stem; the exhaust valve is raised, and the edge of its bevel is smeared with a paste formed of thick oil and emery powder. The grinding is accomplished by rotating the valve on its seat by means of a screw-driver or wimble; the paste being renewed and the process continued until the valve seat is left light and polished, with no trace of the black specks indicating corrosion. The oil and emery paste is then wiped off the valve and seating and the process is finished with the use of a paste of water and powdered pumice.

During the process of regrinding, it is necessary to stop the entrance to the cylinder combustion space with a wad of cotton or waste rags, in order to prevent any of the emery from entering the cylinder where it will work havoc by scoring the sweep walls.

**Unusual Noises.**—There are many troubles of varying gravity that are manifested by no other symptoms than noises, more or less regular, during the operation of the engine. Such noises always indicate trouble, and should not be ignored by the careful motorist.

There are certain rhythmic sounds that are always produced during the operation of a gasoline engine, and the motorist soon learns to recognize them. They are the regular rattle of the automatic inlet valves, the roar of the gears and cams, and the puffing of the exhaust.

Present-day engines are far less noisy than those built several years ago, principally on account of:

1. Better balance of the moving parts.
2. More efficient and better adjusted mufflers.
3. The extensive use of mechanically operated inlet valves.
4. Better gears and cams.
5. The use of housed gears.

As described by motor authorities, unusual noises, indicating trouble, may be described as:

1. Knocking.
2. Squeaking.
3. Hissing or puffing.
4. Numerous irregular puffs and pops.

**Knocking in the Cylinder.**—The form of unusual noise commonly described as "knocking" consists of a regular and continuous tapping in the cylinder, which is so unlike any sound usual and normal to operation that, once heard, it cannot be mistaken.

**Knocking Caused by Over-Rich Mixture.**—Knocking, with all the features of that caused by an over-early spark, may sometimes result from an excessively rich mixture, which may ignite too slowly or too rapidly. Here, as in the general operation of the engine, the rule holds that spark-advance and charge-enriching amount to the same thing, so far as the results are concerned.

If retarding the spark from the extreme lead fails to overcome the knock, the mixture may be throttled with good probability of success.

**Other Causes of Knocking in the Cylinder.**—The knock caused by a premature spark is a heavy pound. The knock caused by some other defects is often less severe. Among other causes of knocking may be mentioned:

1. Defective lubrication or burned oil, leading to a tendency to overheat and seize. This trouble develops rapidly, and demands instant attention, as soon as recognized.

2. Over-late or disordered ignition, producing an explosion during the suction or exhaust strokes. Such an explosion has very little force and is best described as a "pop."

3. Loose or broken piston rings.

4. Broken wrist, or gudgeon, pin in the piston. This is the part of the engine that receives a large share of stress in a high-compression engine, such as is used on most pleasure carriages at the present time.

5. Irregular wear in the cylinder.

As mentioned by numerous authorities, the placing of the spark plug in the exact centre of the combustion space occasions a peculiarly sharp knock, which may be stopped by advancing or retarding the spark from the one point of trouble.

This explanation of the trouble is questioned by others, and is probably over-rated.

**Knocking Outside the Cylinder.**—Knocking, or long-continued tapping or pounding, is not always within the cylinder itself. The effect may result from several mechanical causes, such as:

1. Loose bearings at the wrist or crank pin, giving one knock at the moment of explosion, and another at the change of stroke.

2. Lack of alignment between the connecting rod and the crank pin or wrist pin, which forms a very serious source of trouble. An engine will run with its connecting rod and bearings out of line, but the trouble should, of course, be remedied at the first opportunity.

3. Loose, worn or broken parts at the bearings, in the fly-wheel or in some nut or bolt. Considerable trouble may be caused by a loose fly-wheel, which is a derangement particularly difficult to determine.

**Squeaking in the Engine.**—Squeaking, evidently caused by the rubbing of one part upon another, is a sure sign of insufficent lubrication, probably in some bearing outside of the cylinder, although perhaps at the wrist pin of the piston. Faulty lubrication between the piston and cylinder wall would produce much more serious results than noise, as already stated.

**Wheezing.**—A wheezing sound, evidently due to the escape of gas or air under pressure, and sometimes amounting to a

squeak, is often caused by loose or worn piston rings or scoring of the cylinder bore. The causes of this trouble are, as already suggested:

1. Deficient lubrication, producing a tendency to seize.

2. Misalignment of wrist pin and crank pin, or a bent rod, causing the bore to wear oval. This trouble generally results from repeated back-firing, from an over-early spark and the other causes specified.

The signs of a worn cylinder bore or loose or broken piston rings should be immediately observed. They indicate the most serious occasions of loss and failure possible in a gas engine.

**Hissing or Puffing Sounds.**—While leakage at the piston gives forth a sound that may be described as "wheezing," on account of the imperfect venting of the compressed gas, the escape of such gas into the atmosphere is accompanied by hisses or puffs. Such sounds indicate the probability of leaks:

1. At the gasket in the cylinder head, if a joint exists above the piston.

2. At the insertion of the spark plug, due to a worn screw thread or washer.

3. At the valve seats, due to pitting or to an improper fit of the valve.

Leaks of this character are liable to occasion continuous cracking sounds during the firing stroke.

# CHAPTER TWENTY-NINE.

## OPERATING APPARATUS OF A GASOLINE VEHICLE.

**Essentials of a Gasoline Vehicle.**—Every vehicle propelled by a hydro-carbon, or internal-combustion, engine, popularly known as a "gasoline engine," must have a transmission gear, for varying the ratio of speed and power transmitted to the road wheels. The transmission gear is connected to the engine shaft through a clutch, which may be thrown into engagement, to start the vehicle, and thrown out again to stop it.

It is necessary to use some form of throw-out clutch, because it would be difficult to start the engine with the machinery and running gear connected.

It is desirable to use a speed-reducing and changing transmission, between the engine and the road wheels, because the internal-combustion engine is less flexible than the steam engine, and requires a reducing gear to effect a rational economy. Without such a gear, the road wheels may be driven direct from the engine shaft, and changes of speed and power-effect produced by throttling, as already explained. The fact remains, however, that a much more powerful engine would be required than is now used on any vehicle. This is true because, with every throttling of the charge of a gas engine, the initial pressures are reduced, with a consequent reduction of the explosion and the mean effective pressures. In order, therefore, to run at moderate speeds, the engine would have to be throttled down to one-half or one-third its normal power. In ascending hills full power would often be required, and this would be far in excess of what is generally used.

The force of these remarks becomes apparent when we remember that the best efficiency of a gas engine is obtained by maintaining as nearly as possible a constant speed and power output.

The French designer, Vallee, drove his vehicles from the engine shaft through leather belting. Duryea uses a two-speed transmission, doing all his driving, except hill-climbing, on the high gear, and varying the speed by throttling. Both use very high-powered engines, in order to allow a wide range of throttling, from maximum to minimum power without danger of failure.

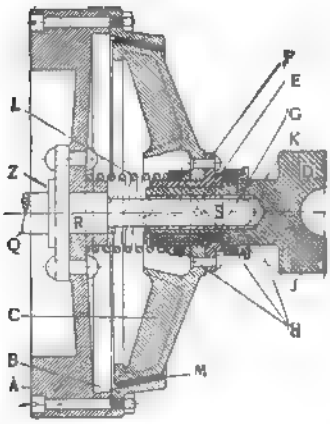



FIG 241.

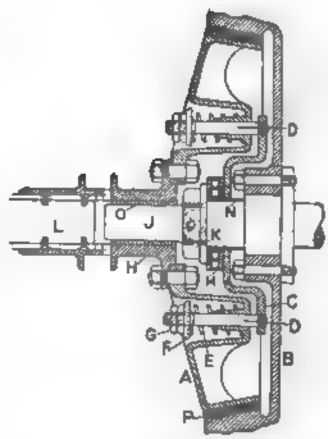



FIG 242.

FIG. 241.—Internal Cone Clutch of the Peerless Car. A, engine fly-wheel; B, female cone; C, male cone; D, universal coupling on male cone; E, bushing on D; F, collar keyed on D; G, key, H, ball bearings for taking up the thrust on disengaging clutch; J, flange on ball cone; K, receptacle on D for operating yoke; L, spiral spring for retaining clutch surface contact; M, leather band riveted on C, giving good friction surface; Q, main shaft, R, portion of shaft turned down to fit fly-wheel; S, portion of shaft turned down to receive clutch sleeve; Z, flange to which fly-wheel is bolted.

FIG. 242. External Cone Clutch of the Pope-Toledo Car A, fly-wheel clutch cone; B, fly-wheel; C, fly-wheel clutch stud plate; D, D, clutch spring studs; E, clutch spring; F, spring retainer; G, retainer lock nut; H, sliding sleeve for setting clutch; J, crank shaft end; K, crank shaft nut; L, tail shaft; M, ball thrust collar; N, ball thrust bush; O, sliding sleeve bush; P, clutch cone leather.

**Forms of Clutch.**—There are four forms of clutch in use on gasoline propelled vehicles:

1. Cone Clutches.
2. Drum and Band Clutches.
3. Expanding Ring Clutches.
4. Compression Disc Clutches.

**Requirements in Clutches.**—The leading requirements in a serviceable clutch are:

1. Gradual engagement, in order to avoid jerks due to too sudden throwing on of the power.

2. Large contact surfaces.

**Forms of Transmission Gear.**—There are four forms of transmission gear in use at the present time:

1. Sliding-Spur, or Clash-Gear Transmissions, which may be distinguished in two forms:

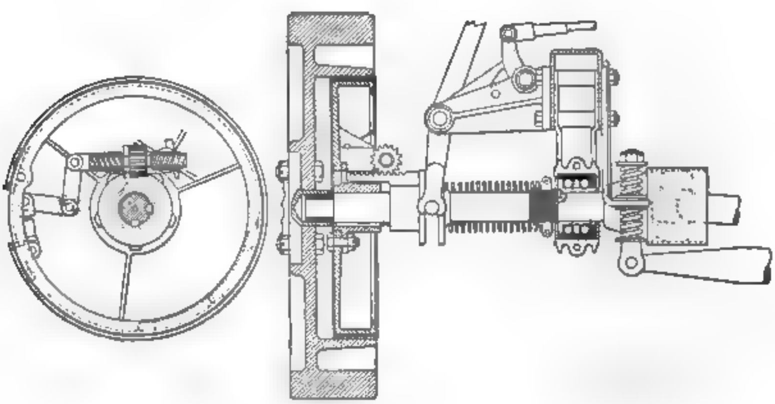


FIG. 243.—End View and Cross Section of the Packard Expanding Ring Clutch.

*a.* One-lever, sliding-sleeve gears, such as the Panhard-Levassor, Decauville, Riker, Packard and Toledo.

*b.* One-lever, selective-finger or gridiron slot transmissions, such as the Daimler, Columbia, Knox, and numerous other forms used on modern gasoline cars.

2. Meshing-Spur, or Individual--Clutch Transmissions.

Prominent among these may be mentioned the old Winton and Haynes-Apperson gears.

3. Planetary Transmissions.

Among planetary transmissions may be mentioned the Duryea, Olds and Cadillac.

4. Friction-Disc Transmissions.

In addition to these may be mentioned the belt and pulley transmission of the early Daimler vehicles and others.

**Cone Clutches.**—The cone clutch is the typical form, and was formerly in practically universal use. As shown in accompanying figures, cone clutches consist of two members: a dish-shaped ring, secured to the face of the fly-wheel, and a truncated cone, carried by a sleeve sliding on the main shaft, and held in close fit by means of a spring. The first member is called the "female cone," the second, the "male cone."

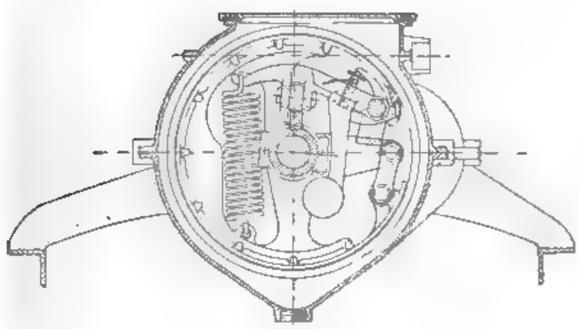


FIG. 244.—Mechanism of the Expanding Ring Clutch of the Columbia Light Car.

There are two varieties of cone clutch: the external cone clutch, in which the male cone is forced against the fly-wheel from the rear; and the internal cone clutch, in which the male cone is contained within the other member and is forced into contact from the front. The latter, or self-contained clutch, is a generally favored pattern. In both forms of cone clutch the contact is between a metal surface and one of leather or fibre. Because it is essential that no oil or grit be allowed to collect on the friction surfaces, the internal cone clutch is preferable, as enabling the surfaces to be more readily protected.

**Cone Clutch Efficiency.**—In order to achieve good power transmission by means of a clutch, two things are essential:

1. Sufficient friction surface.

2. Proper angularity of the cone.

The angularity generally adopted is between 12° and 15°, generally nearer the latter, which affords a friction surface of about ⅛ the fly-wheel diameter in breadth. To increase or decrease the angle of the cone would neutralize the friction effect.

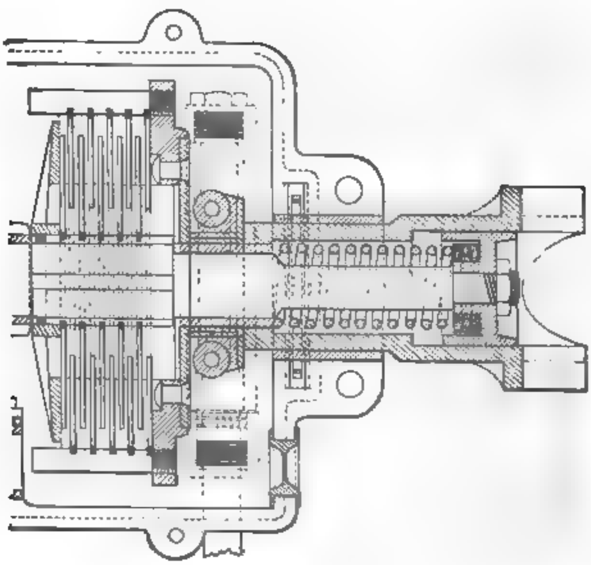


FIG. 245.—MultipleDisc Clutch, sectioned to show construction.

**Troubles with Cone Clutches.**—Although cone clutches possess the advantage of simple construction, and may be readily thrown in and out of action, they are subject to two grave defects:

1. Unless skillfully handled, the power will be thrown on with a jerk, not gradually, as it should be, thus jarring the machinery and annoying the passengers.

2. The friction surfaces, when worn, are liable to slip on each other, thus losing power and jerking rather than pulling the machinery.

In order to avoid the first difficulty several designers have placed small spiral springs at intervals on the surface of the male cone, or between the cones, thus rendering the grip between the surfaces gradual. Such springs may act efficiently, but are objectionable as complicating construction.

**Drum and Band Clutches.**—Clutches of the drum and band type are really only variations of the form of brakes most common on motor carriages. They are generally used in connection with planetary, or epicyclic, transmissions, and consist simply in leather or fibre rings, which are compressed against the periphery of drums, in order to prevent rotation. They will be described in connection with planetary transmissions.

**Expanding Ring Clutches.**—Expanding ring clutches are used by several designers as convenient substitutes for the ordinary cone clutches. Mechanically, they are identical with the expanding ring brakes, except for the fact that their use accomplishes the connection into a working unit of two rotating shafts. According to engineering authorities, the cone clutch and the expanding band clutch are similar in theory, the angularity of the cone in the cone clutch being the same as the angle of the operating levers in the band clutch. The friction surfaces of the ring clutch may be both of metal or the ring may be faced with fibre.

**Compression Disc Clutches.**—The disc clutch is the latest and most satisfactory solution of the clutch problem. Briefly described, it consists of three or more metal discs secured alternately to the clutch shaft and to the face of the engine fly-wheel. By the pressure of a powerful spring the discs are forced together, thus involving a close driving contact, which cannot slip. Unlike other forms of clutch, the disc clutch should be soaked with oil. This contact is gradually made, as is not the case with all other clutches.

**Friction-Disc Transmissions.**—The friction-disc transmission undoubtedly has a large future. It obviates all the diffi-

culties incident upon the use of sliding spur gears or planetary speed changers, and also does away with clutches of all descriptions. In practical service upon all weights of vehicle it has already demonstrated its ability to transmit power as efficiently as any other device. Briefly described, the friction transmission consists of two elements, the driving friction disc and the driven friction disc. The simplest form, the driven disc is set on a shaft at right angles to the driving disc, and is

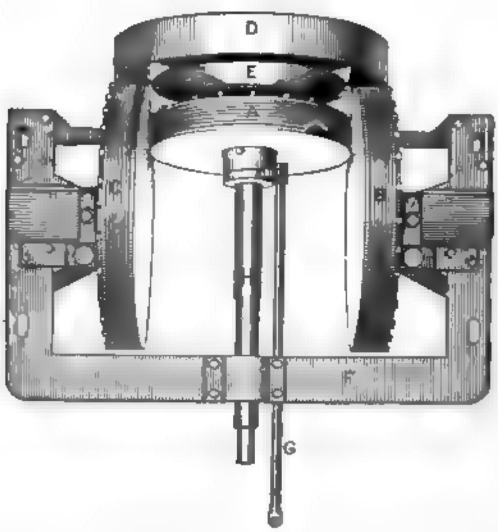



**FIG. 346.—A Type of Friction Transmission. A is the driven disc on the transmission shaft; H, B and C are friction idlers driven from driving disc, D; E, is the clutch; F, the transmission frame; G, the lever for changing the speeds by shifting disc, H, along shaft, H.**

rotated by friction contact between its edge and the face of the driver. When the edge of the driven disc is driven on a circle nearest the periphery of the driver, its speed is greatest. As it is slid along its shaft, toward the centre of the driver, as may be done by means of a squared portion or splines, its speed is constantly decreased. At the center of the driving disc it ceases to rotate. If slid beyond the centre of the driver, its motion is reversed.

**Requirements in Friction Driving.** There are only two requirements in an efficient friction drive:

1. Firm contact between the rotating discs.

2. Large driving surface.

The greatest practical problem occurs in connection with the large driving surface. Experience shows that, when a wheel is friction-driven on its edge, the greater proportion of the driving is done on a somewhat narrow line running around the middle of the breadth, leaving an area of slipping on either side. The result is a retarding effect. This difficulty may be obviated in several ways, among which may be mentioned:

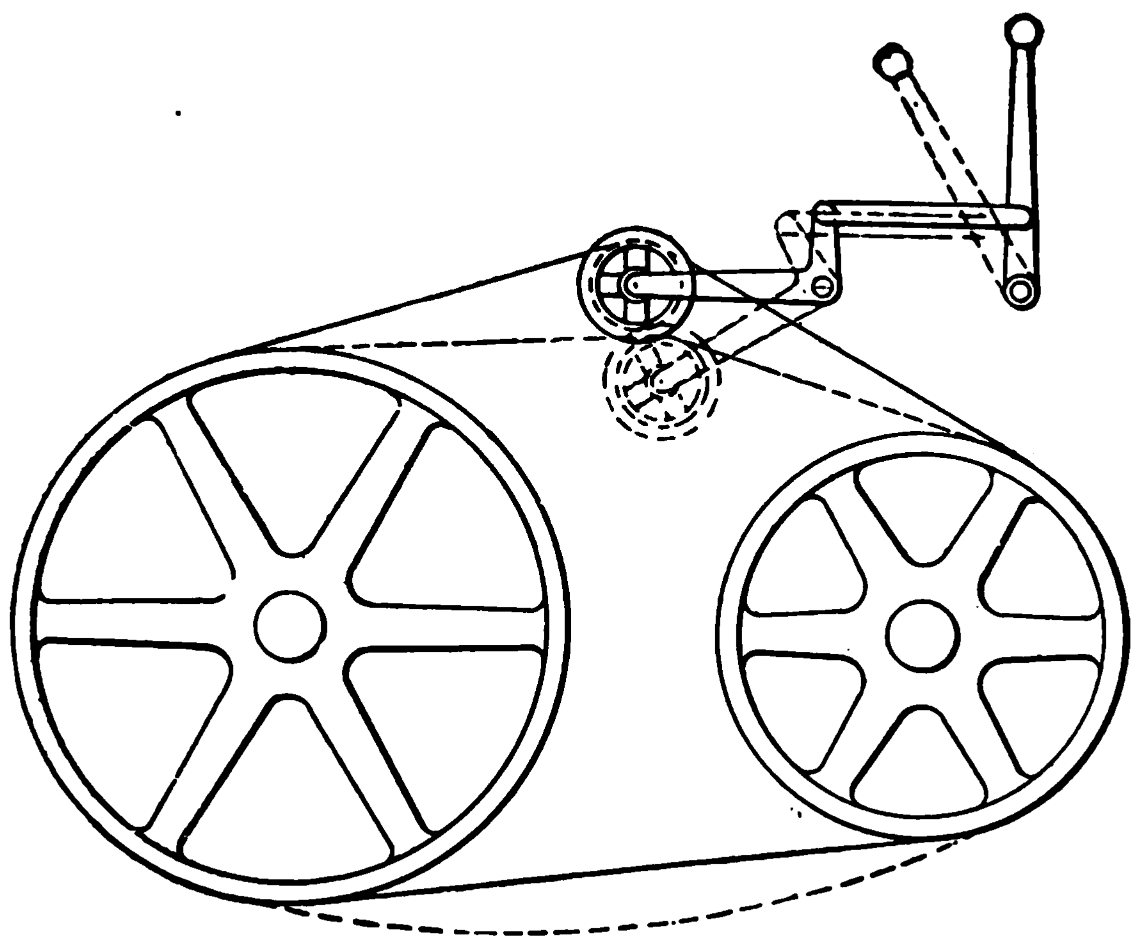


FIG. 247.—Diagram of the Belt Transmission, used on the early Daimler carriages.

1. Beveling the two friction wheels. This is impossible in automobile transmissions, as permitting no speed-changing or reversal.

2. Constructing the driven disc in three sectional discs, representing, respectively, the middle driving line and the areas of slip on either side. The three discs may then be arranged to interact like the sprocket and two bevels of a differential gear. All slipping is thus perfectly compensated, while a good

breadth of driving surface is attained. Such an arrangement, while possessing some advantages, is altogether too complicated for use on an automobile.

3. Transmitting the power through friction idlers from the driving to the driven disc. This is the arrangement adopted in several types of friction transmission. One is shown in the accompanying figure. Here two idlers, one on either side, turn at right angles to the shaft of the driver. Between them, and turning on a shaft in line with that of the driver, is the driven disc. The motion and power are transmitted from the driver to the two idler discs, which, in turn, rotate the driven disc. The driven disc may be slid forward or backward between the two idlers, thus receiving varying degrees of speed or being reversed, as already explained.

**The Daimler Belt and Pulley Transmission.**—The belt transmission, used with the earlier Daimler carriages consisted of four pulleys regularly increasing in size, keyed to the main shaft, and four others regularly decreasing in size in the same order, keyed to the countershaft. Four belts connected these eight pulleys, and the power was thrown upon any one pair as desired, by tightening the belt with an idler pulley mounted on a suitably disposed bell crank. By this method it was possible to obtain four speeds forward on an even roadway, or to vary the power in ascending grades.

**Variable-Cone Pulley Transmission.**—A far more suggestive form of transmission, in which is embodied the very necessary feature of gradual shifting of speeds, is found in the variable cone transmission, as used on the Fouillarion vehicles, built in France. As shown in the accompanying figure, the relative speeds of the driving shafts and countershaft may be varied by changing the diameters of the driving and driven pulleys. In this figure, *A* is a frame on which are mounted two shafts, *B* and *B*, turning in the bearings, *C* and *C*. On each of these shafts is a feather, *D*, on which slide double cones, *F, F, F, F*. To the apex,

*J*, of each of these cones are attached fingers, *S, S, S, S,* which are screwed to the heads, *G, G, G, G,* as shown. A handle, *P,* pivoted at *N,* may be turned in either direction, actuating the levers, *L, L, L, L* and *K, K, K, K;* thus modifying the belted diameter of either pulley from that shown in the upper of the two to that shown in the lower one. Thus the speed ratios in the two may be varied to any desired point. The levers, *K, K, K, K,*

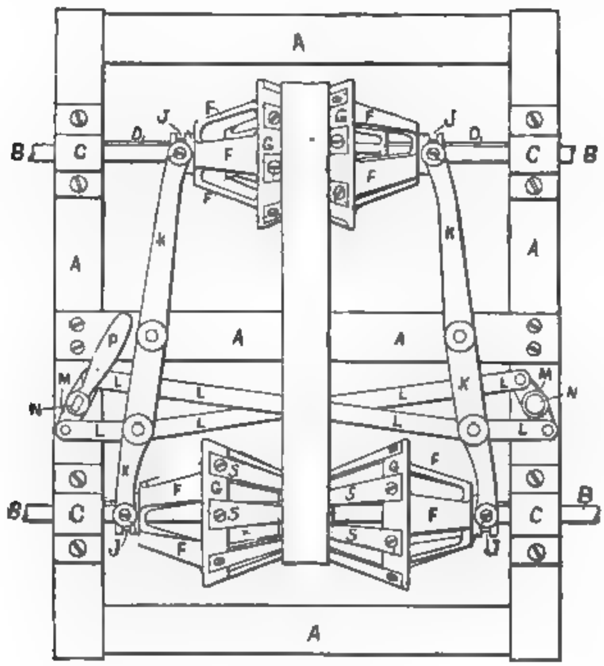



FIG. 248.—Diagram of a Variable Cone Pulley Transmission.

by forked connections, actuate the cones, causing them to slide along the feathers, *D, D, D, D,* at the spools, *J, J, J, J.*

**The Sliding or Clash Gear Transmission.**—The familiar clash gear transmission was originated by Panhard-Levassor, who were the real originators of the modern type of motor carriage. The original Panhard transmission is shown in the accompanying

figure. It consists of two shafts, *A* and *C*, the former carrying on a square portion the sliding sleeve, *B*, upon which are four gears of varying diameter. On the shaft, *C*, are keyed four gears, whose diameters vary inversely with those on *A*. At the right-hand extremity of the shaft, *A*, is carried the male cone of the main clutch, which, when held in gear by a pressure of the spring, *F*, enables the transmission of power direct from the crank to the shaft, *A*. The clutch may be thrown out by lever, *E*, which acts to pull the shaft, *A*, to the left, compressing the spring, *F*. The sleeve, *B*, may be shifted on the main shaft by lever, *D*, which is connected as indicated. When as in the cut, the gear, $B^1$, is meshed with the gear, $C^1$, the car will have its slowest speed forward, and the act of shifting the gears to the left from that position will raise the speed at a regularly increasing ratio; the meshing of $B^2$ and $C^2$, giving the second speed forward, and the other gears the next two increasing speeds. Similarly, also, in the act of shifting the sleeve from the extreme left position, when gear, $B^4$, is meshed with gear $C^4$, there will be a similarly regular decrease of ratio in their speed.

The motion is transmitted from shaft, *C*, through the bevel gear, *G*, which, as shown in both sections of the cut, meshes with another bevel on the transverse jack shaft. This bevel, *H*, and a similar bevel, *L*, on the case containing the differential gear, are keyed to the sleeve, *M*, which works over the centre-divided countershaft, at two extremities of which are the sprocket pinions for driving direct to each of the rear wheels. As long as the bevel, *G*, drives on *H*, as shown, the motion of the carriage is forward, at any speed determined by the relative positions of the shifting gears on the two shafts, *B* and *C*. In order to reverse the motion of the carriage, the sleeve, *M*, is shifted upon the lever, acting on the spool, *K*, so that *H* is pushed out of mesh with *G*, and *L* is thrown in. By this process, as is obvious, although the rotation of *G* continues in the same direction, the movement imparted to *L* will be the reverse of that previously imparted to *H*. Thus the reverse has the same number of speed

and power combinations as the forward motion. It is also obvious that, by shifting the sleeve, *M*, a certain distance, the driving connections to the main shaft, through the differential, *J*, will be thrown off altogether. This is the operation necessarily preceding the throwing on of the brake, the drum of which is on the countershaft, just beyond the thimble, *H*.

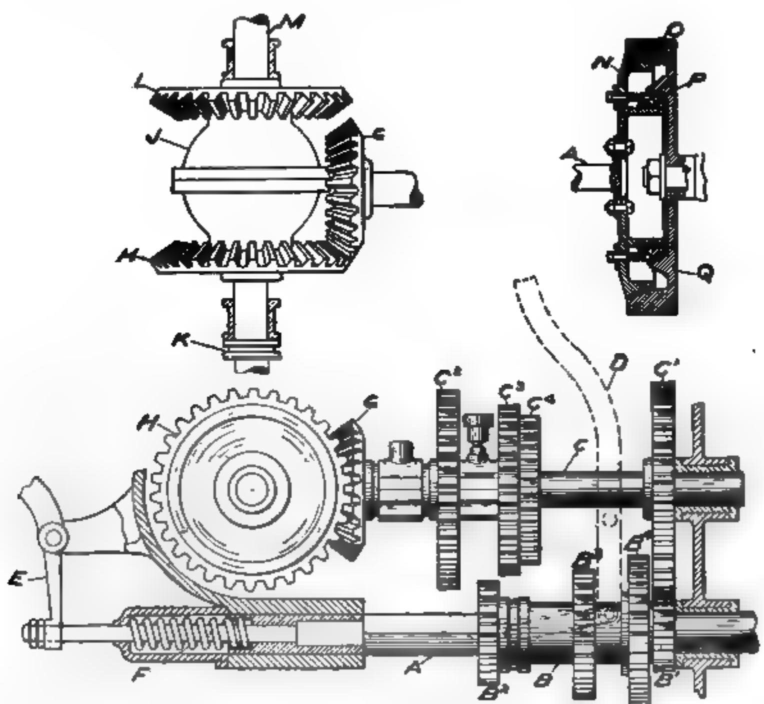


FIG. 249.—Details of the Panhard-Levassor Change Speed Gear.

On the later models of the Panhard carriages a simplified variation of the transmission gear is used, which drives through a single bevel gear on the jack shaft, constantly in mesh with the bevel on the secondary driven shaft, or top shaft,—thus requiring no shifting of the differential to throw the reverse bevel. A third shaft set parallel to the clutch shaft, carries two spur gears, as shown in the diagram.

The four forward speeds and reverse may be operated with a single lever, which may be thrown progressively forward for each forward speed and brought all the way back for the reverse. The manner of operation is simple. The shifting lever operates a rod sliding parallel to the three shafts, and from it extends an arm that engages the spool on the sliding sleeve, and also slides along the reverse shaft. At the position shown in the diagram the lowest forward speed is engaged, through the meshing of the spurs, *A* and *E*. By bringing the hand lever all the way back, the sleeve is moved clear to the right, and *A* and *E* are thrown

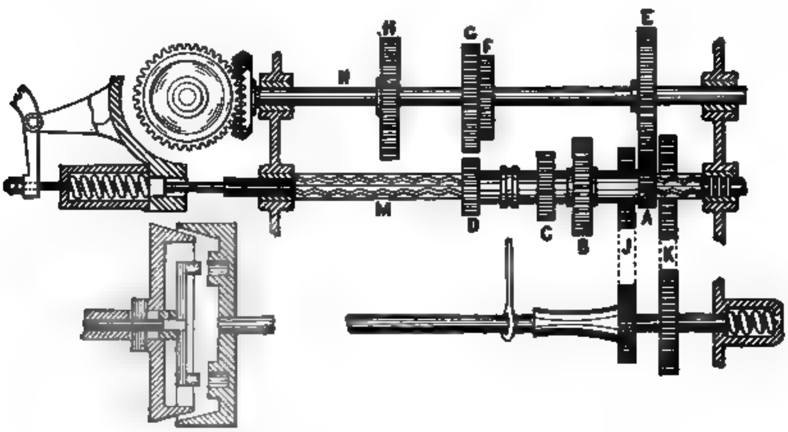
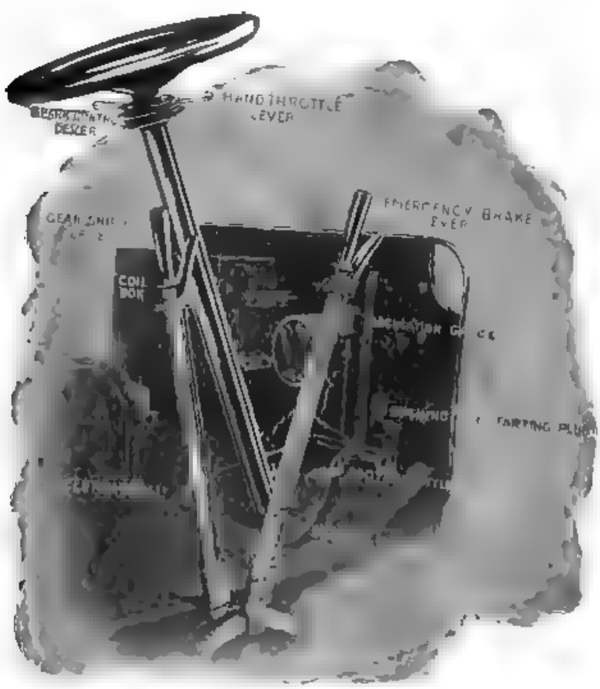



FIG. 250.—Sketch of the Improved Panhard-Levassor Transmission and Clutch.

out of mesh. At the same time, the arm of the sliding gear shifter meets a raised portion of the reverse shaft, as shown, pushes it to the right, depressing the spring. The spur, *J*, is then meshed with *E*, and *K* with *A*—The movement of the main clutch shaft being thus transmitted to the top shaft through the engagement and rotation of the third, or reverse, shaft.

**Single Lever Gear Controls.**—Very many sliding-gear transmissions have been used on cars of large power, and in most cases the control has been of the general description shown in an ac-

companying figure of the Riker-Locomobile levers and control apparatus. Here, the inner of the two levers sliding in notched quadrants may be moved forward through the three forward speeds, and pulled back for the reverse, the clutch being, meantime, thrown out. On account of the high power and ready control of the engine, it is possible to operate the carriage on the high gear most of the time, thus requiring that the lever be man-




251.—Control Levers and Appliances of the Riker Car.

ipulated only when hill-climbing or other special necessities demand. The outer lever represents the emergency hub brake, while the main brake on the differential drum is operated by a speed pedal to the right of the steering pillar. Similarly, the clutch may be thrown by depressing the lever to the left of the pillar. The spark and handle throttle handles are set at the end

of the rods beside the steering pillar, within each reach of the right and left hand, respectively. But an auxiliary throttle pedal or accelerator is operated by a pedal beside the brake; thus enabling the carriage to be perfectly operated without removing either hand from the steering wheel.

**Direct Drive Transmissions.**—A notable feature of many clash-gear transmissions of recent years has been the direct drive on the high gear, with the primary advantage of obtaining full power, without loss, due to transmission through several

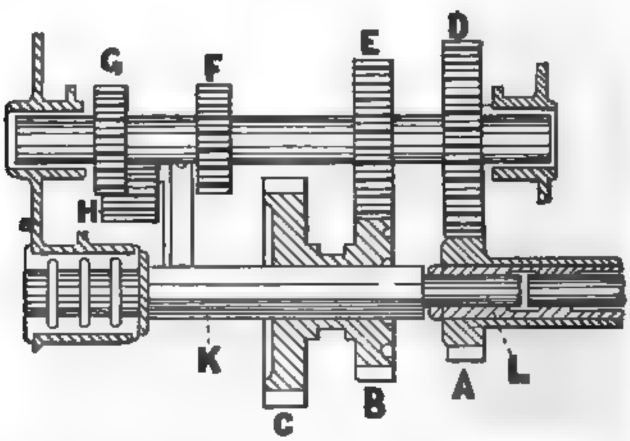



FIG. 252.—Diagram of the Decauville Transmission Gear. A is the spur pinion at the end of the clutch shaft; B and C, spurs on the sliding sleeve; D, E, F, G spurs keyed to the second motion shaft; H, the reverse pinion, constantly in mesh with G, and giving the reverse when in mesh with C also; K, the square portion of the drive shaft; L, portion of same journaled into the clutch shaft.

spurs, on the top speed. The result is usually effected by the use of a double driving shaft, one section of which rotates within the other, until the two are locked together by the engagement of an external with an internal gear, acting together as a tooth or claw clutch Notable among such transmissions is the Decauville, which has served as the type for several familiar models.

**The Decauville Transmission.**—The Decauville transmission, as shown in the accompanying sectional diagram, consists essentially of two parallel shafts. Of these, the countershaft carries

four keyed spurs, *D, E, F, G,* the largest of which, *D,* is constantly in mesh, with pinion, *A,* on the clutch shaft. The clutch shaft, however, terminates with this constantly meshed spur, being bored longitudinally, so as to afford a bearing, at L, for one end of a second shaft, *K,* arranged continuous with it, but turning separately. The entire length of this second shaft between bearings is of square section, so that the double-faced pinion, *B C,* may be slid from end to end by means of a fork set at one end of the gear-shifting lever.

When the double-faced gear is moved to the left, so that the pinion, *F,* on the countershaft meshes with the larger of the two, *C,* on the square shaft, the low speed forward is obtained. By sliding the sleeve to the right, so as to bring the larger countershaft gear, *E,* into mesh with the smaller one, *B,* on the square shaft, the second speed is obtained. By sliding the sleeve all the way to the right, so that, by a form of claw clutch its right-hand gear, *B,* grips the pinion, *A,* on the clutch shaft, the highest forward speed is obtained the drive being then continuous from the motor to the road wheels. The reverse is obtained when the sliding sleeve gears are moved all the way to the left so that the larger of the two, *C,* meshes with an idler pinion, *H,* constantly driven from the end gear, *G,* of the countershaft, by which means the rotation of the square section shaft, and of the road wheels is reversed.

**The Locomobile Transmission.**—The transmission gear of the Locomobile car is of a similar type, and is arranged to give three forward speeds and one reverse, the high speed being direct from the main shaft. The cone clutch, which is normally held against the face of the fly-wheel by coiled compression springs, is bolted to a flanged sleeve carried on the squared end of a short shaft, *I,* terminating in the spur pinion, *A.* This pinion, as shown in the figure, is always in mesh with the spur gear, *B,* on a parallel secondary shaft, 2, and continues to turn the secondary shaft so long as the engine is in motion. The spindle on which *A* turns has a longitudinal bore serving as a

bearing for the shaft, 3. terminating in the bevel pinion, *C*, in mesh with the bevel gear, *D*, on the differential drum of the "jack shaft," 4. The shaft, 3, is square through its entire length between bearings, and carries the sliding pinions, *E* and *F*. Since its rotation is independent of the clutch sleeve, 1, it follows that all movements except the high speed forward, must be transmitted from the secondary shaft, 2, through the pinions, *E* and *F*, and since these may be slid into a neutral position the shaft, 2, may rotate without driving the carriage. The slow speed forward is obtained when gears, *E* and *G*, are in mesh, the second faster speed, when *F* and *H* engage,

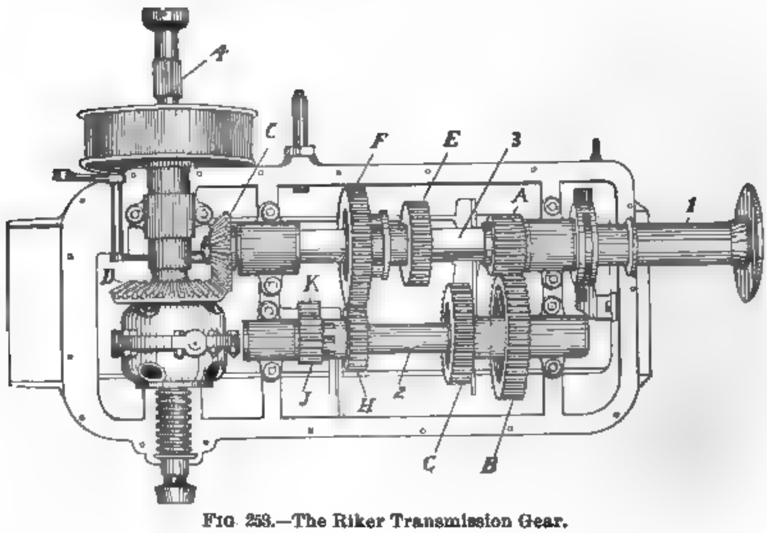



FIG. 253.—The Riker Transmission Gear.

and the reverse, when *F* engages idler, *K*, which is driven from the secondary shaft through pinion, J. For the high speed forward, *E* is slid to the right until internal teeth in the face engage the external teeth on A, thus locking the two and making the movement of shaft, 3, continuous with that of sleeve, 1, and driving the carriage direct from the fly-wheel shaft..

**The Packard Transmission.**—The transmission of the Packard car is of the same general type as the last two mentioned,

except that it is operated by two levers, one for shifting the forward gears and one for engaging the reverse.

The Packard car is driven by propeller shaft and bevel gear to the rear axle, and possesses the uncommon advantage of having the transmission to the gear, against the axle, thus saving the trouble and lost motion encountered with a long propeller shaft direct to the driving bevel, and, according to claims, serving to steady the driving bevel.

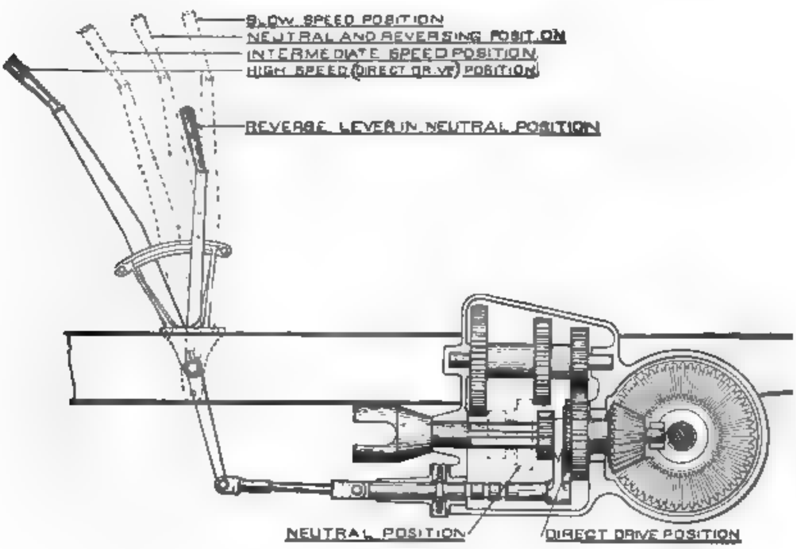



FIG. 264.—Diagram of Control Levers and Transmission of the Packard Car

As shown in the accompanying diagram, it consists of three shafts: (1) the drive shaft connected by a universal joint to the clutch, and square through the greater part of its length to allow of sliding a sleeve holding two spur gears; (2) the bevel pinion shaft carrying a single spur gear at its inner end and bored to serve as a bearing for the drive shaft; (3) the second motion shaft, to which are keyed three spur gears, two of them of diameters suitable to mesh consecutively with the sliding gears on the drive shaft, giving the lowest, intermediate speeds, and the third constantly in mesh with the single gear on the bevel shaft.

The top speed as in the Decauville, and other modern transmissions, is obtained by sliding the two-gear sleeve all the way back (to the right in the diagram), so that its teeth mesh with internal teeth cut in the circumference of the bevel shaft gear, thus making the drive direct from the motor. The reverse is obtained when the gears on the sliding sleeve are in the neutral position (indicated by the dotted outlines in the cut), by operating the short reverse lever, thus causing an idler pinion, hung on a bell crank to be thrown into mesh with the forward (left) end of the drive and top shafts.

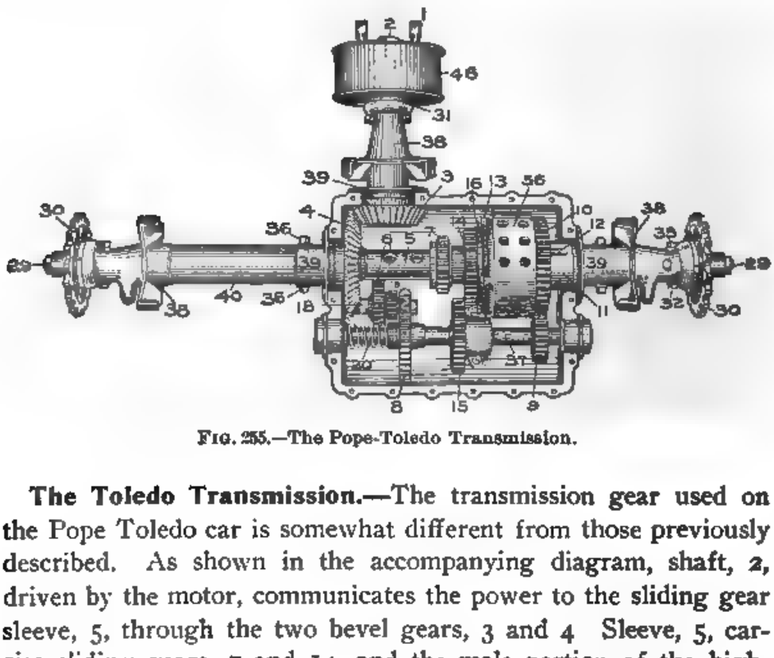



FIG. 255.—The Pope-Toledo Transmission.

**The Toledo Transmission.**—The transmission gear used on the Pope Toledo car is somewhat different from those previously described. As shown in the accompanying diagram, shaft, 2, driven by the motor, communicates the power to the sliding gear sleeve, 5, through the two bevel gears, 3 and 4 Sleeve, 5, carries sliding gears, 7 and 14, and the male portion of the high-speed gear clutch. These parts are free to move endwise, but are prevented from turning independently by a long feather, 6, on sleeve, 5. The sleeve, 5, is free to turn on the transverse transmission, or jack, shaft, 29. Directly behind this shaft is a second shaft, 37, which carries, gears 8, 9 and 15.

For the first speed forward gear, 7, is meshed with gear, 8, and the motion is transmitted by gear 9, on the second shaft, to gear, 10 on the Jack shaft, 29. The second speed forward is obtained by meshing gears, 14 and 15, and transmitting the motion to jack shaft, 29 as before. To obtain the third, or high, speed, the sleeve carrying gears, 7 and 14, is moved to the right, with the result that gear, 14, acts against pins, 13, disengaging gear, 10, from the counter shaft, and engaging clutch, 16, making the differential, 56, and the countershaft, 29, continuous with sleeve, 5, and thus driving direct from bevel, 4. The reverse is effected when the gear, 7, is moved to the left and meshed with gear, 18, on the reverse shaft, shown below and between sleeve, 5, and countershaft, 37. At the same time, gear, 8, is moved to the left against the pressure of spring, 20, coming into mesh with reverse pinion, 19. The drive is thus from 7 to 18, through 19 to 8, and thence through 9 and 10 to the countershaft, 29. The lever quadrant is notched to show the proper positions for the several speeds described.

**Selective Spur Transmissions.**—Great troubles with early sliding spur transmissions lay in the facts that, in shifting from high to low gears, all intermediate speeds were engaged; also, that a careless or inexperienced driver was never sure to fully engage two spurs, thus entailing considerable wear and breakage of gear teeth. To meet these objections the "selective-finger" transmission as it is generally called, was devised. The earliest example of this type of gear was that used on Cannstadt-Daimler cars, shown in accompanying diagrams. It was the first car to use the gridiron, or H-shaped, quadrant slot, now so popular. Like later forms of selective transmission, it affected all changes of forward and reverse movements by the use of a single lever. The slot used is typical.

The operation of the common change-speed and reversing lever consists in the use of a double H-shaped slot, or grid sector, so that the lever may be moved backward or forward in any one of three parallel channels, or shifted sideways from one to another

by means of a fourth channel cut at right angles to the other three, like the cross line of the letter H.

The hand lever is pivoted to a cross spindle, which may be slid lengthwise in its bearings whenever the hand lever is brought to the middle transverse slot of the grid sector. The four sliding spurs on the square section of the main shaft are in two sections

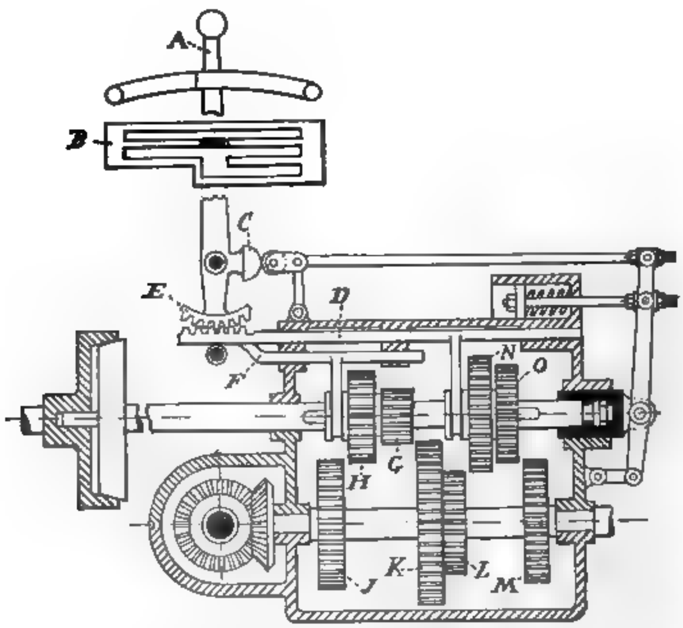



FIG. 256.—Transmission Gear of the Cannstadt-Daimler Carriage shown in the last figure. Here, A is the hand lever, B, the gridiron quadrant; C, a dog on the lever for throwing out the clutch in shifting the gears; E, toothed sector at end of A for actuating rack rods D and F (see next figure); G and H, low speed gears on the clutch shaft; J and K, low-speed gears on the second, or driving, shaft; N and O, high-speed gears on the clutch shaft; L and M, high-speed gears on the second shaft. H and G are shifted on square portion of shaft by rack, F; N and O by rack, D.

of two spurs each. Each section is shifted by an arm projecting downward from a horizontal rod bearing a rack on the outer end. Furthermore, these two rack rods are set side by side, so that a toothed sector on the lower extremity of the hand lever may engage either one of the racks, operating either of the two lower speeds when the lever is moving in the left-hand slot, and either

of the two higher speeds when it is moving in the second slot. When drawn to the backward position in either slot, it operates the lower of the two speeds, and, in the forward position, the higher of the two. In order to reverse the movement of the carriage, the hand lever is brought to the mid-position on the grid-sector, shifted all the way to the right, and moved forward. This operation is possible because the cross spindle to which the lever is pivoted carries an arm projecting downward at right angles, and terminating in another toothed sector, that, when the lever is slid over to the right, as just explained, engages a third

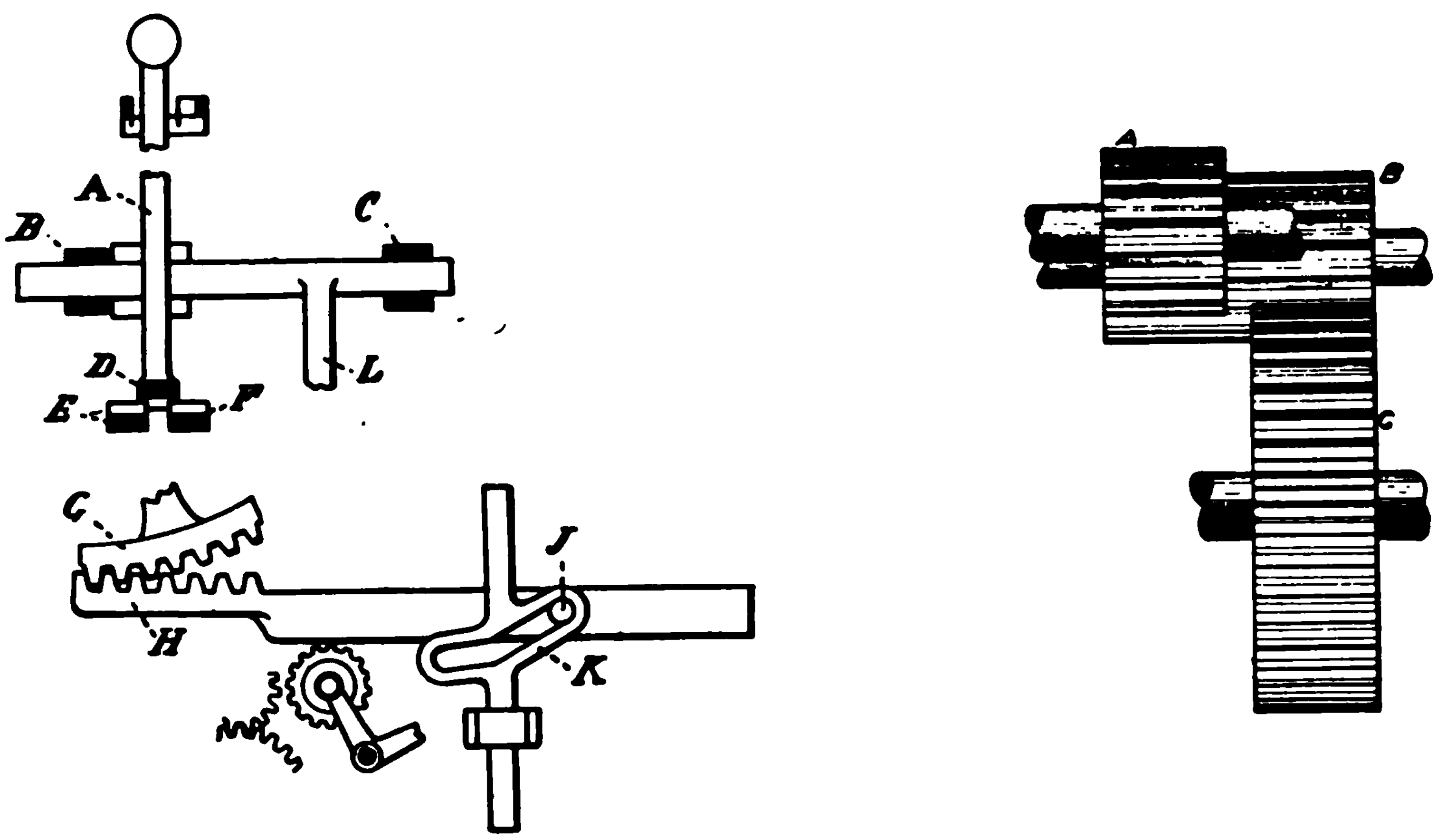



**FIG. 257.—Details of Side-Shifting Change Lever of the Cannstadt-Daimler Car.**

rack bar geared to throw in the reverse pinion, *B* (see figure of reverse gear). The arm, *K*, in the same figure, carries an upward turned slot in a position to engage a pin on the reverse rack-shaft, so that, when that shaft is slid forward by the interworking of the rack and sector, the arm is lifted and pinion, *B*, brought into position by the operation of a bell-crank. In addition to the toothed sector set at its lower extremity, the hand lever has an arm at right angles exactly at the pivotal point, so that, when the lever is brought to the transverse slot of the grid-sector, this arm presses upon a bar, thus throwing out the clutch.

The entire operation may be understood from the figures of the reverse apparatus. Here, A is the lever, pivoted between bearings, B and C. D is the toothed sector, which may be shifted to engage either of the rack rods, E or F; L is a downward extension from the pivot rod of A, carrying the sector, G, which may be slid into mesh with rack, H. By sliding rack, H, to the right, as in the cut, pin, J, lifts the rod attached to the curved slot, K, throwing in the reverse pinion. The manner of doing this is shown with the pinions, A and C, meshing with the long reverse pinion, B.

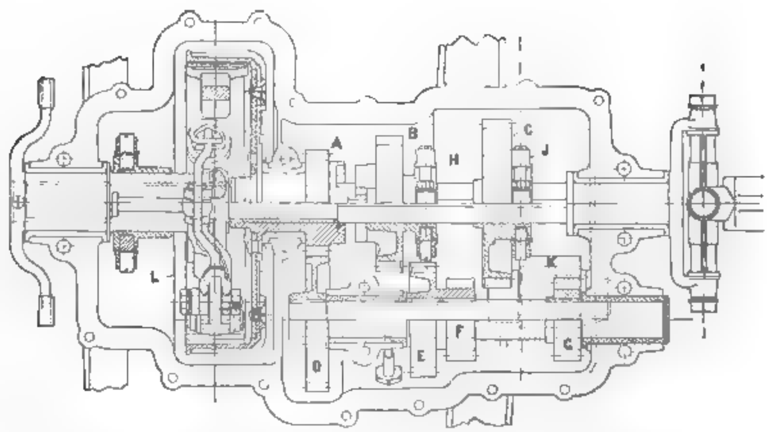



FIG. 258.—Transmission and Clutch of the Columbia Light Car. A, spur gear on the clutch shaft; B and C, spurs on the squared second shaft, the first shifted by fork hung at H, by lever, H (last figure), the second by fork at J by lever, J. D, E, F, G, three-speed pinions keyed to countershaft; K, pinion giving reverse when in mesh with C and G; L, clutch.

**The Columbia Transmission.**—The selective transmission of the Columbia light car closely resembles that used on the Decauville in the method of obtaining the several speeds and the reverse. As shown in the diagram, the driving shaft consists of two parts; the clutch shaft carrying gear, *A*, and the sleeve shaft carrying gears, *B* and *C*. Gears, *A* and *D*, are constantly in mesh. The low speed is obtained when gears, *F* and *C*, are meshed; the second speed with *E* and *B* meshed; the top speed with *B* moved forward (to the left) so as to engage the claw clutch and make a driving union with *A*; the reverse, when *C*

is moved backward (to the right), so as to mesh with idler pinion, *K*, which is permanently meshed with *G*, This transmission differs from the Decauville in the fact that gears, *B* and *C*, are moved independently by forks attached at *H* and *J*, respectively. This transmission is not controlled by a single lever and gridiron quadrant, but by two levers, *H* and *J*, as shown in the diagram of the control.

As the control is typical of modern systems, it is worthy passing notice. The clutch controls foot pedal, *D*, to the left of the

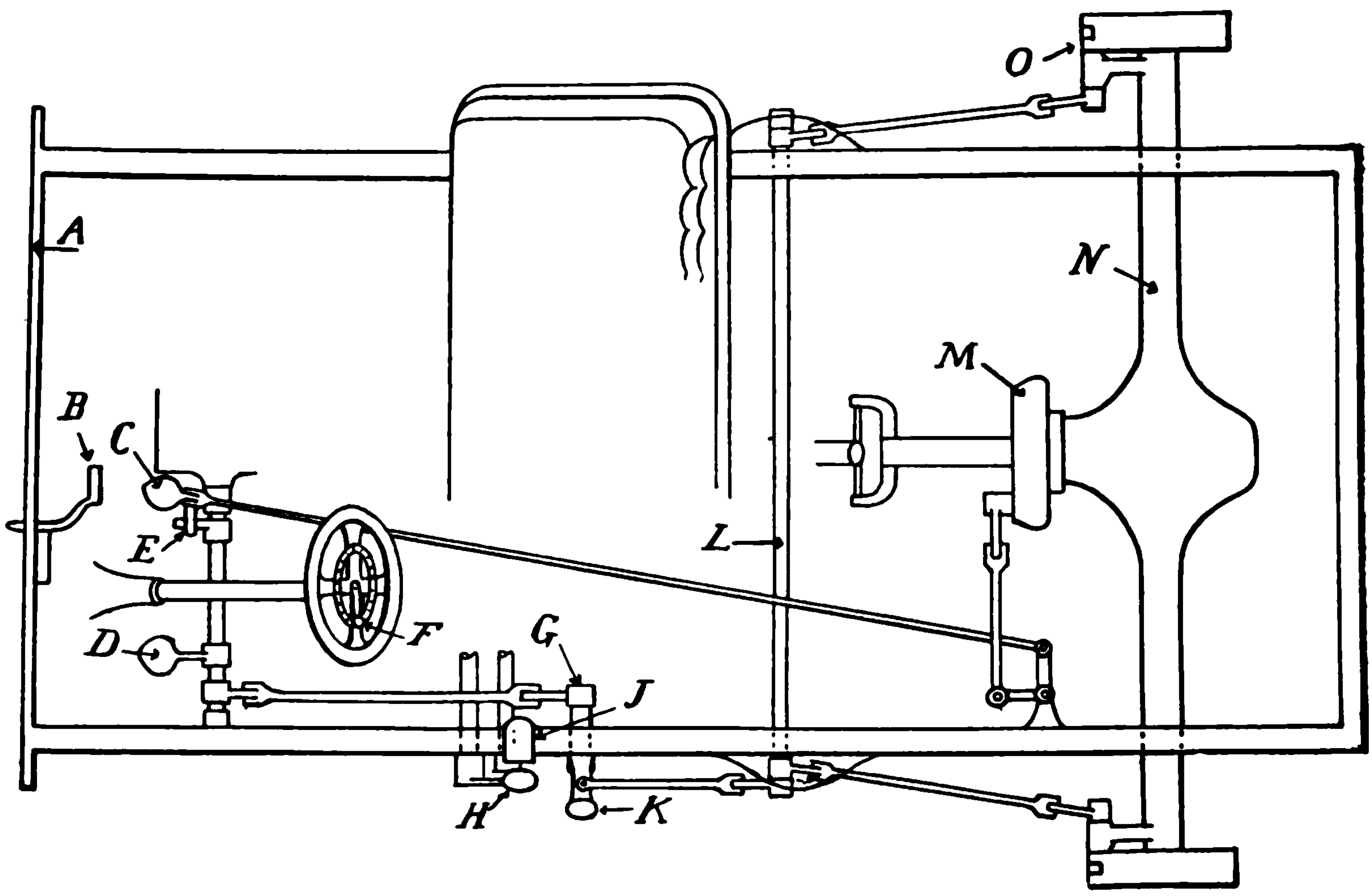



FIG. 259.—Plan Showing Lever and Control System of the Columbia Two-cylinder Light Carriage. A is the dash; B, foot accelerator lever for controlling engine; C, foot break lever; D, clutch lever; E, clutch interlock, requiring that clutch be thrown before brakes are set; F, ignition-timing lever on steering wheel; G. clutch interlock; H, second and third speed lever; J, first speed and reverse lever; K, hub emergency brake lever; L, brake rocker; M, expanding brake on driving shaft; N, rear live axle; O, hub brake.

steering post, opens the friction clutch, when pressed down, and closes it, when allowed to rise. It is fixed on a shaft having a small finger, *E*, interlocking the foot brake lever, *C*, on the right of the steering post, so, that, when the clutch pedal is pressed down, no effect is exerted upon the brake pedal. But owing to a pin projecting in front of the small interlock on the clutch shaft, when the brake pedal is pressed down the clutch

pedal is caused to go back and release the clutch. The brake connections run to the rear and connect by a bell crank lever to the expanding brake band on the transmission shaft at *M*. This brake is applied beyond all the universal joints on the propeller shaft so that they receive no braking strains.

The emergency brake lever, *K*, also connects to the clutch pedal by a slip interlock, *G*, so that, when it is pressed down, the clutch pedal is also pulled off. Its connections run aft and connect to band brakes, *O*, on the driving wheel hubs.

The speed change levers, *H* and *J*, are shown on the left side directly in front of the emergency brake lever. As in this vehicle the engine power is very high in proportion to the weight of the vehicle, ordinary service requires that the middle and the high gears are the ones most used. They are thus controlled by one handle, *H*, which is made conspicuous. For such backing and filling as is necessary in turning in close quarters, other handle, *K*, gives the reverse and low gear ahead. To set the medium gear, the conspicuous handle is pulled back as far as it will go; for the high speed it is to be pushed ahead as far as it will go regardless of notches or other indexes. A small snap indicates the off position. Similarly, to set the reverse gear, the second lever is pulled back as far as it will go, and, to set the low gear ahead, it is pushed forward to the end of the slot. One lever cannot be moved unless the other is in the off position

**The Knox-Mercedes Transmission.**—A form of transmission introduced on the Mercedes car, and adopted on the Knox vehicles in the United States, represents a type worthy careful attention. As shown in the accompanying diagram, the main shaft, *A*, of large diameter, has four spur gears, *C, D, E*, sliding on fluted keys or feathers integral with the shaft. It is coupled directly to the clutch shaft, and runs in bearings, *PP*. The second motion shaft, *B*, runs in bearings, $P^1P^1$, and has gears, *F, G, H*, rigidly secured on it. The differential gears are enclosed in the perforated case, *M*, and brake drum, *N*, is firmly secured to the case. Two bevel gears are secured to periphery of M, one of which, *L*, is the direct high gear drive, meshing with pinion,

*I,* and the other is the drive for lower speeds, meshing with pinion, *J,* on the second motion shaft. Bevel pinion, *I,* is integral with internal gear, *V,* and runs on ball bearings on shaft, *A,* except when it is clutched to this shaft by sliding the gear *E,* into mesh with *V,* by means of fork, *Q,* and shifter bar, $Y^2$, giving fourth speed on direct drive. On this drive bevel gears, *J* and *K,* and shaft, *B,* are running idle and gears, *F, G, H,* are not in mesh. Meshing, *E,* with *H,* gives the third speed.

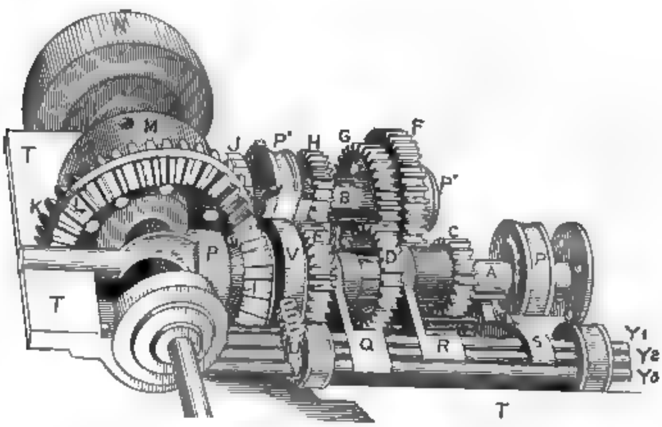



FIG. 261.--The Knox Mercedes Selective Finger Transmission, showing method of shifting gears by three shifter bars, $Y_1$, $Y_2$, $Y_3$, and of driving through two bevel gears to the jack shaft.

By means of fork, *R,* and shifter bar, $Y^3$, *D* is meshed with *G* for second speed or *C* with *F* for first speed, *C* and *D* being integral.

The reverse gear is mounted between two supports on the bottom of case, and is shifted by fork, *S,* and shifter bar $Y^1$, into mesh with, *C* and *F* for the reverse motion.

The bars are shifted by a single hand lever working in a gate quadrant on the selective system. The selector box is dust proof and contains a simple device which positively locks, in their neutral position, all the shifter bars except the one in use. On direct drive none of the gears on the shaft, *B,* are in mesh and bevels, *J* and *K,* are running idle.

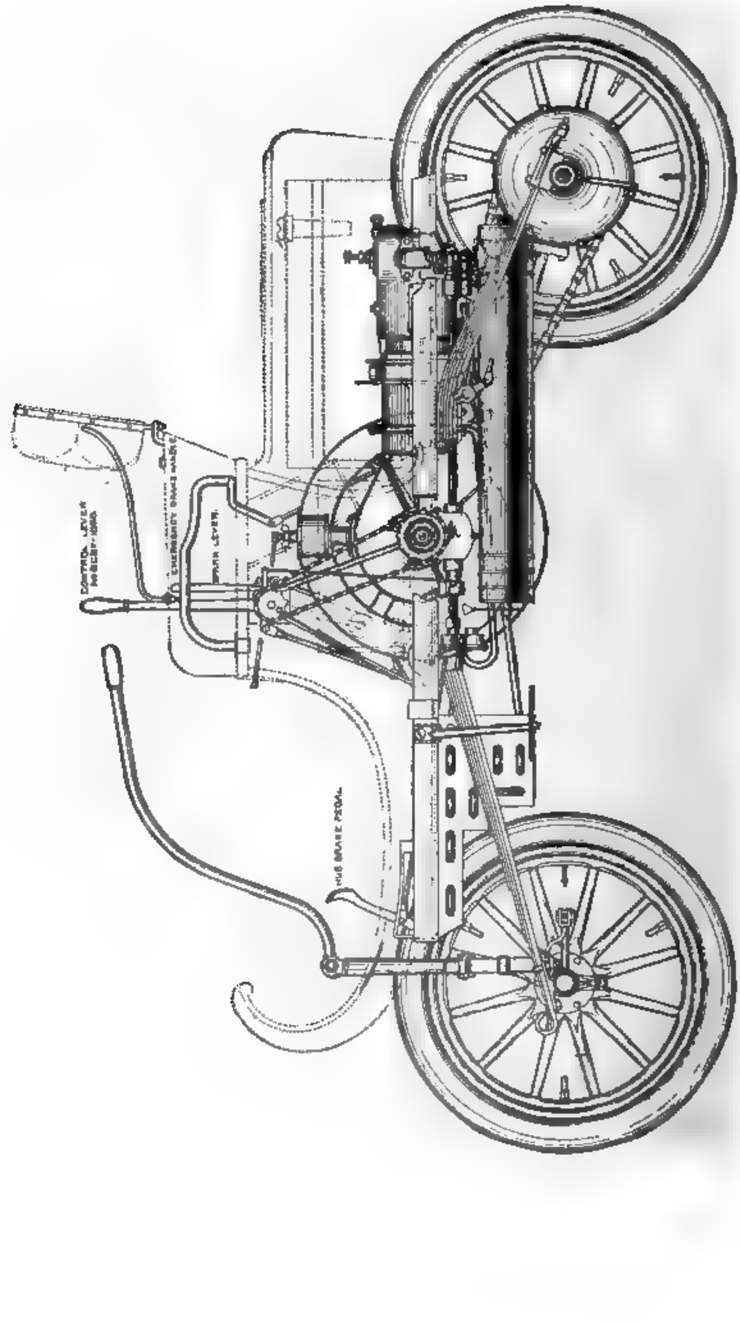



FIG. 201.—Side Elevation of the Oldsmobile Single-cylinder Runabout, showing operative apparatus.

**The Oldsmobile Transmission.**—The two-speed and reverse transmission of the Oldsmobile is of the planetary gear type. The reverse and low speed forward are operated by band and drum clutches, and the high speed forward by a friction compression clutch. A single shaft carrying three eccentrics, with the throws in different directions, serves to actuate all three—the two former, by tightening bands around the brake drums, the latter,

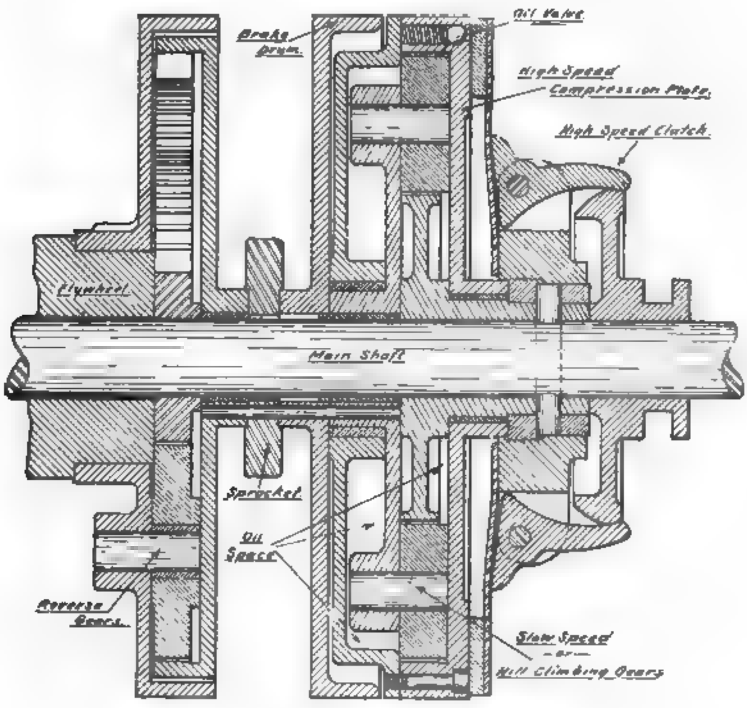



FIG. 252.—Section of Oldsmobile Two-Speed and Reverse Transmission.

through a bell crank moving in a direction longitudinal to the main shaft. As shown in the sectional diagram, two spur gears are keyed to the main shaft. Each of these gears meshes with planetary pinions studded to a frame or spider arranged to turn with a sleeve loose on the shaft. Furthermore, the pinions mesh with internal gears, so that the entire system may rotate at once,

or the planet pinions may turn on their axes over the internal gears. Close examination of the section will show that the internal gear of the reverse, the sprocket, the main brake drum and the pinion frame of the forward gear are rigidly held together by a pin, so as to rotate as a unit. When neither of the bands is applied the rotation of the two spurs on the main shaft is transmitted through the planetary pinions to the brake drums, leaving the driving apparatus stationary. The reason for this is obvious for, since the internal gear of the reverse and the pinion frame of the forward speed are rigidly connected on one sleeve, they obviously cannot rotate in opposite directions. When, however, the band is applied to the forward speed clutch drum, which is the internal gear, the spur causes the pinions to rotate on their axes and travel around within the internal gear, imparting rotative movement in the opposite direction to their frame and the sleeve holding the sprocket and the internal gear of the reverse. The clutch drum of the reverse gear is the pinion frame, and this being held rigid by the band, the driving spur rotates the pinions on their axes, causing them to drive the internal gear and the sprocket in the same direction as its own rotation, thus reversing the movement of the carriage. The high speed forward is obtained by throwing in the cone friction clutch shown at the right of the diagram, the effect being to press upon the high speed compression plate, thus holding the pinion frame and internal gear in rigid relation, and causing the entire transmission system to rotate as a compact whole at the speed of the main shaft.

**The Cadillac Carriage.**—The Cadillac gasoline carriage is an American product, combining a number of original features. Its first introduction was in 1903.

As shown in accompanying figures, the machinery and control apparatus are very compactly arranged, and a good idea of the convenience of operation may be obtained. The body frame is of angle-steel, hot riveted and trussed at four points by transverse bars. The motor and transmission gears are hung at the centre of the frame, and the driver's seat is placed directly above. As shown in the cuts of plan and elevation of the Chassis, the arrangement of the control apparatus agrees with that of the standard carriages already described. Here the steering wheel

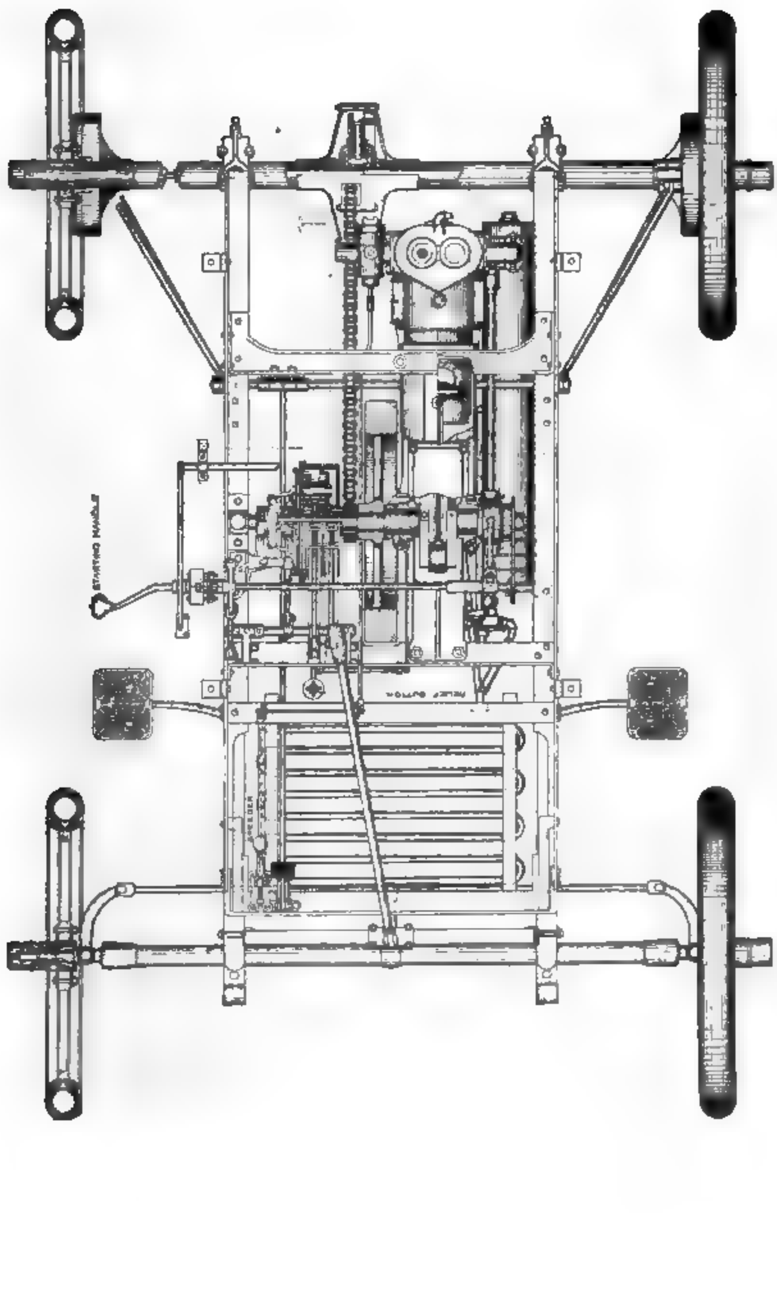



FIG. 283.—Plan View of the Oldsmobile Single-cylinder Runabout.

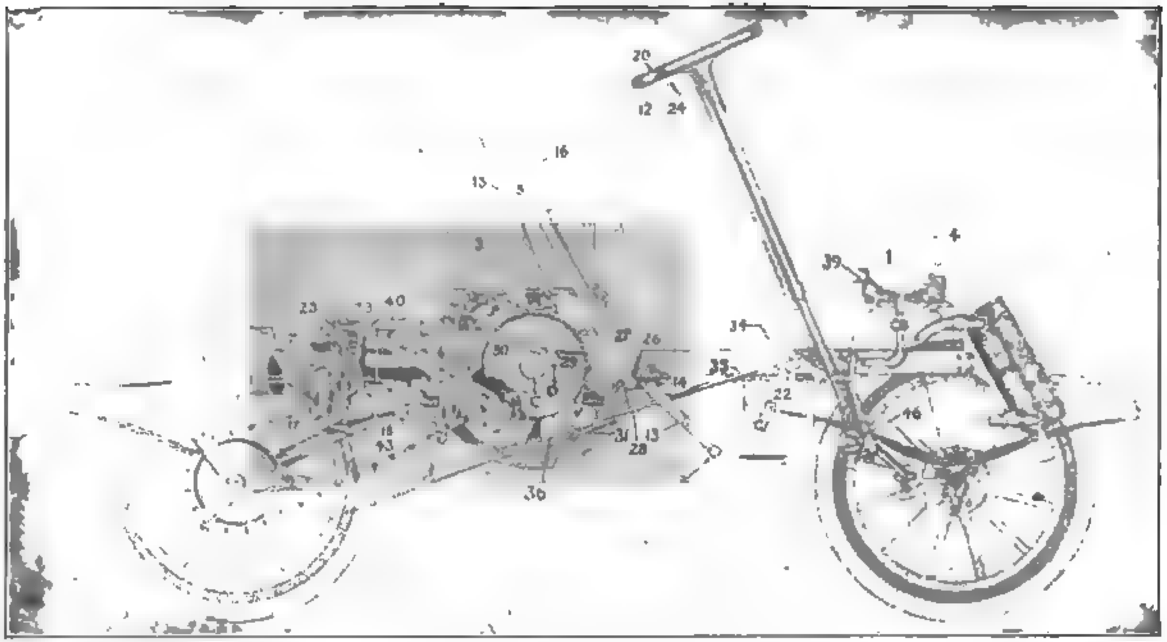



FIG. 284.- Sectional Elevation of the Cadillac Single-cylinder Runabout. The parts are: Water tank (1); gasoline tank (3); vent in water tank (4); plug in gasoline tank top (5); carburetter (7); throttle lever (12); starting crank (13); starting shaft (14); spark lever (15); speed control lever (16); carburetter primer (17); cylinder drain valve (18); steering wheel (20); throttle connection to lever (12) shown at (22); throttle rod (23); throttle quadrant (24); valve lift cam (25); controller shaft (26); high speed control arm (27); reverse control arm (28); rod controlling high speed clutch (29); high-speed clutch (30); rod controlling reverse clutch (31); brake pedal (34); rod for setting brake (35); low speed clutch band (36); coil vibrator (39); grease cups (40 and 43); rack of steering system (46).

(20) carries a quadrant (24), around which works the throttle lever. This lever is fixed at the end of a rod set parallel to the steering pillar, and actuates an arm (22) below the floor, connected by a link (23) to the throttle arm, and moves the cam (25) as already explained in connection with the figure of the engine. By this means the volume of the charge may be constantly regulated. The spark lever, (15) set at the right of the driver's seat, furnishes another means of regulating the engine, advancing or retarding the spark. The top speed and reverse are operated by means of the hand lever (16), while the slow speed is attained by the pressure on the pedal (34) at the left of the

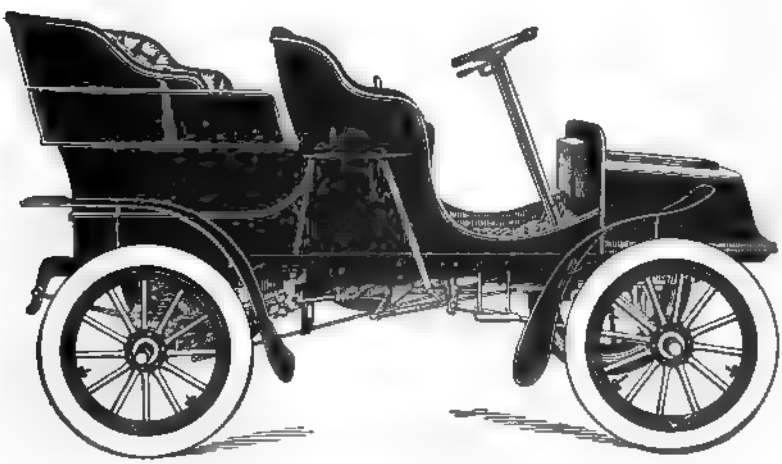


Fig. 265.—Cadillac Car, with Rear Entrance Tonneau.

steering pillar. The pedal at the right acts upon the main brake on the differential drum. When it is pressed upward and forward, it rotates the short transverse shaft to which it is attached, causing an arm to rise and exercise a pull upon a double cable, thus constricting the two brake bands on the differential drum. The reverse gear may also be used as an extra brake, as will be presently explained.

**The Transmission.**—The transmission used on this car is of the planetary type, its theory and operation being readily under-

stood from the figure 267, page 376. As here shown, it consists of the two drums, *H* and *K*, the former of which is the reverse drum, and contains six studs, *L*, holding six spur pinions. Three of these pinions, *E*, are twice the width of the other three, *F*, and all mesh with pinion, *G*, which is of the width of the *F* pinions, and is on a sleeve keyed to the hub of the drum, *K*. The main driving pinion, *D*, is keyed to an extension of the crank shaft, and meshes with the *E* pinions only, on the widened portion which projects beyond the pinions, *F*, as shown in the cut. The left end of the gear case, *C*, is fastened to *H* by screws. The drum, *B*, on which is the internal gear, is continued through the casing, and the sprocket, A, forms part of it. When the brake drum, *H*, with the pinion studs upon it, is held stationary by a band brake; and when pinion, *D*, turns with the shaft in the direction of the arrow upon it, it drives pinion, *E*, in the direction shown by its arrow, and, since *E*'s stud is stationary, *E* in turn drives internal gear, *B*, in the opposite direction. This produces the reverse. To obtain the slow speed, the brake drum, *K*, is held by a brake band, and pinion, *D*, drives pinions, *E*, as heretofore. *E* in turn drives *F*, but as *G* is stationary, since it forms part of the drum, *K*, the pinions, *F*, travel round it with a planetary motion, thus turning the drum, *H*, slowly and causing the pinions, *E*, to turn the internal gear and drum, *B*, even more slowly, but in the same direction as that in which *D* is turning. For the high speed, a leather-faced disc, keyed to the shaft, is pushed against the smooth surface on the right-hand end of drum, *K*, thus locking *K* to the shaft, and causing the whole drum to turn as one unit without any of the gears revolving. When the car is standing still and the engine is running, all the gears are turning, and the drum is revolving idly about the shaft.

It is easy to understand the method of varying the speed and power ratios by the use of this transmission. The control lever (16) is attached to the control shaft (26), which has two arms (27 and 28), on different radii. Arm 27 has attached to its end a rod (29) which engages and controls the high speed clutch (30) in the manner already explained. At the end of the other arm (28) is a rod (31), which engages and controls the reverse brake band (32). If the controlling lever be moved forward, the first arm (27) and its rod (29) cause the high-speed clutch to lock the transmission gearing together into one rotating unit,

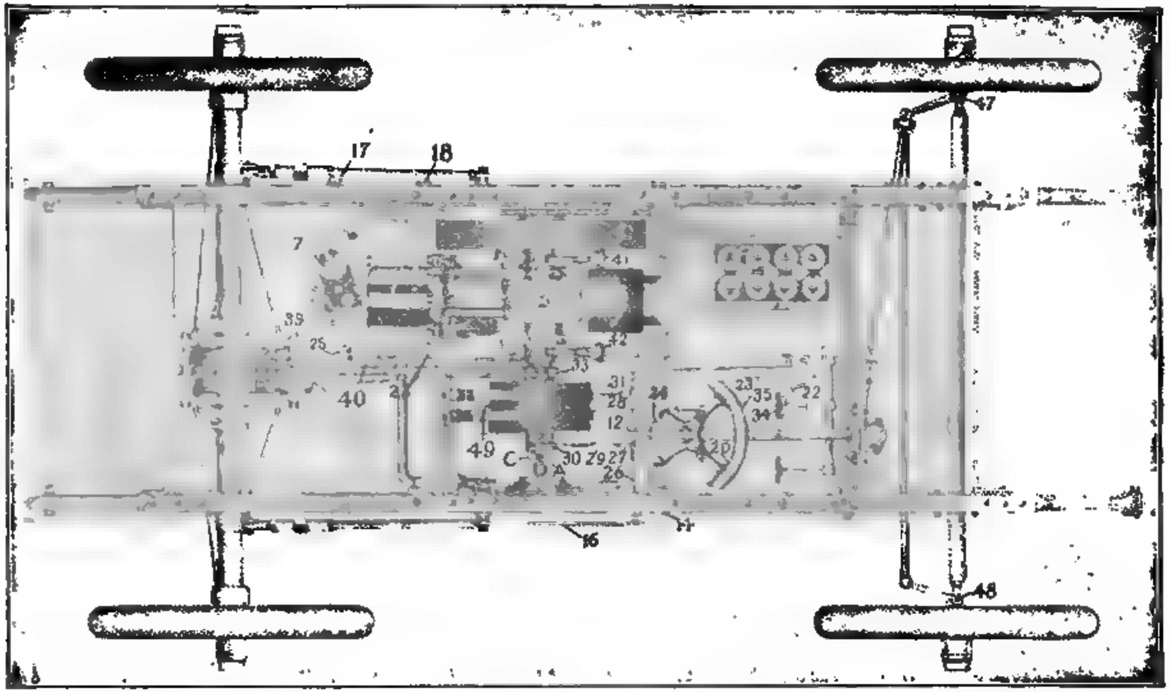



FIG. 266 —Plan View of the Cadillac Single-cylinder Runabout. The parts are: Carburetter (7); throttle lever (12), starting crank shaft (14); speed control lever (16); carburetter primer (17); cylinder drain valve (18); steering wheel (20); throttle connection to lever (12) shown at (22); throttle or valve control rod (23); throttle quadrant (24); valve lift cam (25); speed control shaft (26); high-speed control arm (27); reverse control arm (28); high-speed clutch rod (29); high-speed clutch (30); reverse clutch rod (31); reverse brake band (32); driving sprocket (33); low-speed pedal (34); low-speed rod (35); slow-speed brake band (36); grease cups (39, 40, 41 and 42); stud axles (47 and 48); transmission case (49).

so that it revolves with the engine shaft and acts as an additional fly-wheel, carrying the driving sprocket (33) around with it. If, on the other hand, the control lever (16) be moved backward, the high-speed clutch releases, leaving the engine free to run without driving the carriage. This is the neutral position. If the lever (16) be moved still further back, the rod (31) attached to arm (28) will be drawn forward and will close the reverse brake band upon the reverse drum, *H*, as previously explained. Consequently, the sprocket turns in the reverse direction at low speed. Since the grip of the reverse band may be varied, so as to permit of more or less slip, it is possible to use the reverse as a brake for ordinary needs.

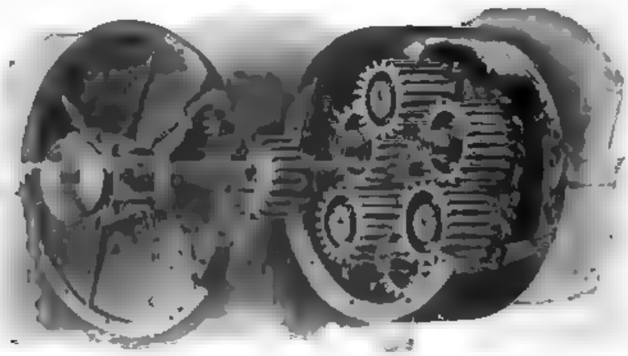


FIG. 267. Diagram of the Cadillac Transmission, giving two forward speeds and one reverse

In throwing in the low speed, the control lever is set in the neutral position, in which both the high speed and reverse clutches are released, and the slow speed pedal (34) is pushed forward and upward by the flat of the foot. When this is done the attached rod (35) is moved, and the slow-speed brake band (36) is moved upon the drum, *K*, thus causing the sprocket to revolve with the engine shaft, but at a greatly reduced rate.

**The Duryea Carriage and Control.**—The well-known Duryea carriage is built without an underframe, the wheel axles, front and rear, being connected direct to either end of the heavily built body. The principal advantages are that greater compactness and accessibility of parts are rendered possible. The three-cylinder

motor already described, is placed beneath the driver's seat with the change-speed gear and other moving parts. This change-gear, or "power drum," as already explained, allows two forward speeds and a reverse, although all ordinary driving is done on the high speed, the parts of the power gear being stationary with relation to each other, and the speed of the carriage being controlled entirely by throttling.

**The Duryea Transmission Gear.**—The transmission gear used on the Duryea carriages, shown in section and part plan

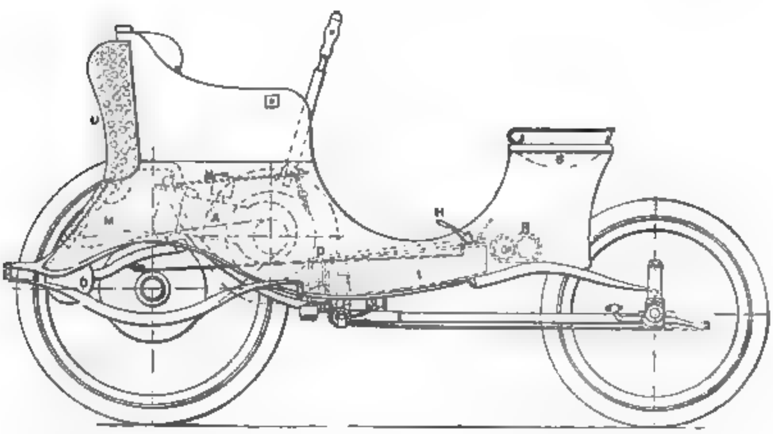


FIG. [illegible].—Elevation of the Duryea Three-cylinder Car. A, the motor; D, the magneto generator, H, brake pedal; I, gasoline tank; M, tubular panel for passage of water from tank, V, to water jacket; N, oil cup on motor; O, muffler; R, 6-cell battery; S, extra seat in front; U, cellular water tank, cooled by draft deflected by wings from side of vehicle.

in the accompanying illustrations, is operated entirely by friction clutches, entirely avoiding the wear and constant danger of breakage involved in the use of shifting gears.

The planet-gear frame is *normally* held in engagement with the sprocket-carrying disc, *D*, by means of the pins, *P*, so that holding the internal gear, *X*, by means of the slow-speed band—the other clutches being released—it carries the sprocket forward at slow speed. Since the planet-gear frame and the disc, *D*, are normally in engagement, it is evident that clutching the ring, *X*, to the disc, *D*, will prevent relative motion of the planet gears

and the internal gear, and thus cause the sprocket to be carried at the speed of the motor. This effect is produced by means of conical friction surfaces on *D*, engaged by complementary surfaces inside the ring, *B*, and the disc, *E*, which surfaces are brought in contact by means of the wedge, *C*, bearing against the disc, *E*, under the roller attached to the lug projecting from the ring, *B*. This wedge, *C*, is operated by a shifting collar, *F*, and toggle link, *G*; a shifting lever, not shown, being attached to the outer ring of the ball bearing, *F'*. The section shows these surfaces in engagement; releasing being effected by moving the

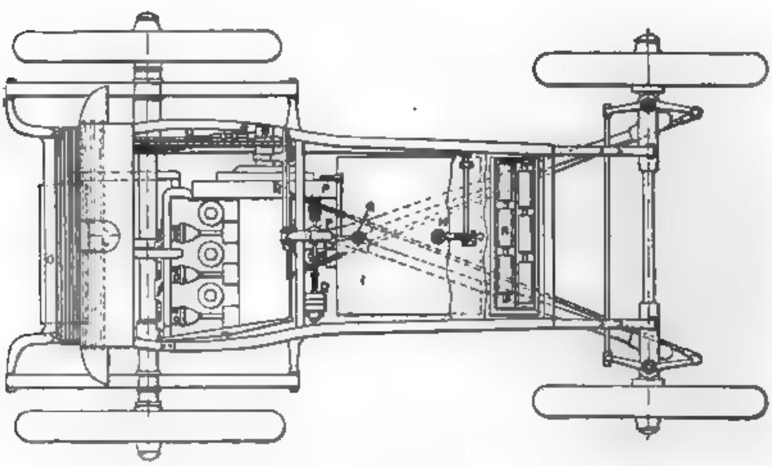


FIG. 269.—Plan View of Duryea Three-cylinder Car. B, bearing for speed gear; C, distance-rod from rear axle for taking up the pull of the chain; D, the magneto-generator; G, pedal for operating the reverse clutch; H, brake pedal, I, gasoline tank; P, central single control lever; R, 6-cell battery. Front axle shorter than rear to prevent skidding and promote ease in turning.

shifting collar, *F*, toward the sprocket, which withdraws the wedge, *C*, and permits the friction surfaces to be separated by the spring shown. The large surfaces and the toggle and wedge arrangement for closing them, secure a very powerful pressure with little shifting effort, while the disc, *D*, is ordinarily surfaced with brass, which, having a higher expansion co-efficient than the cast iron against which it bears, is rapidly heated, in case of slipping, and becomes self-tightening by expansion. Releasing all

the clutches allows the sprocket with its disc, *D*, and the planet-gear frame to stand idle while the internal gear revolves freely in a reverse direction, as shown by the arrows.

The reversing effect is secured by holding the ring, *H*, which is mounted on the arms of the planet-gear frame, in such a manner that the frame may move a short distance before it is stopped

FIG. 270.—Front Elevation of the Duryea Change Speed Gear. The lettering here refers to the same parts as in figure 271, page 380. N marks the position of the lever, M, when pins, P, are inserted in holes. Y, in D. M′ marks the position of lever, M, when pins, P, are raised from holes in D. R and R, arms of the spider, carrying the three idler pinions, A′, and sliding in a groove on H to the pins, T and T′.

by pins, *T′*, which motion moves the lever, *M*, into the dotted position *M′*, and withdraws the pin, *P*, from engagement with the disc, *D*, thus separating the planet-gear frame from the sprocket disc, *D*. Since the pins, *T′*, prevent further movement of the planet-gear frame, while the disc, *D*, is free to move in any direction, it is evident that the motion of the motor will drive

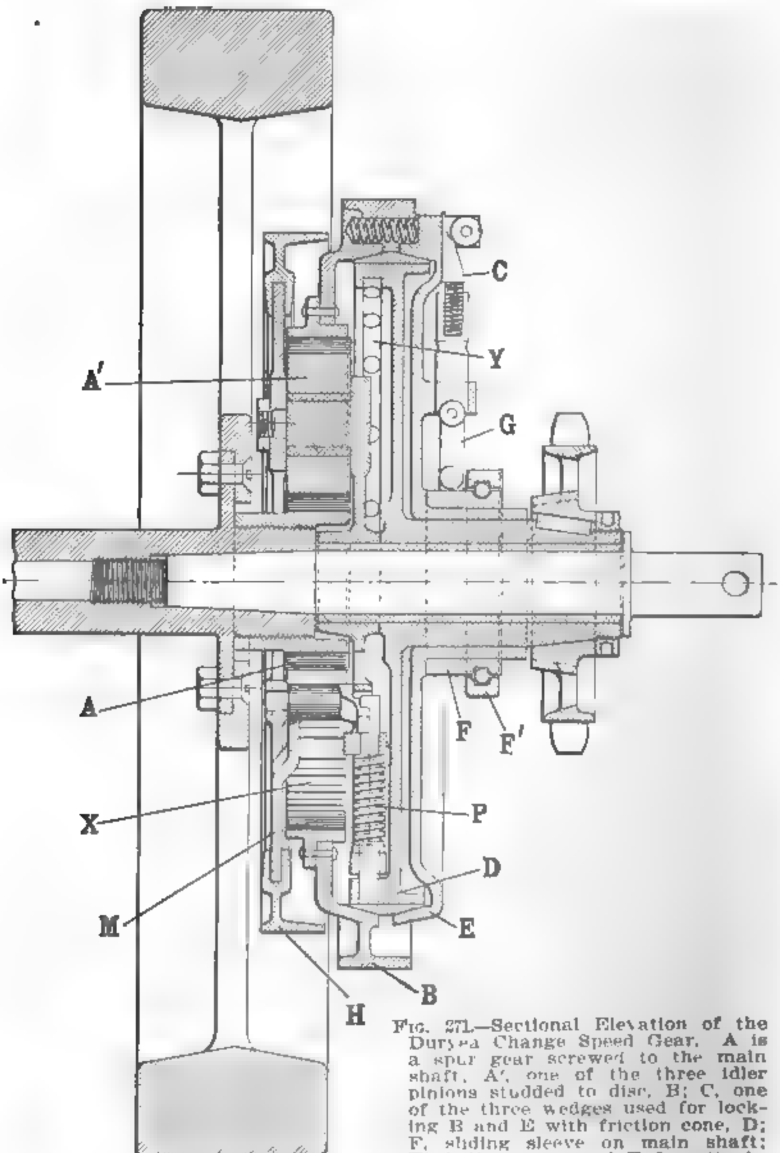



FIG. 271.—Sectional Elevation of the Duryea Change Speed Gear. A is a spur gear screwed to the main shaft, A', one of the three idler pinions studded to disc, B; C, one of the three wedges used for locking B and E with friction cone, D; F, sliding sleeve on main shaft; F', ball race around F for attaching the shifting lever; G, toggle joint operated by shifting sleeve, F; M, lever for raising or lowering pin, P, X, an internal gear on disc, B; Y, a groove containing perforations for admitting pins, P, when H and B are locked together.

the internal gear, *X*, in the reverse direction, and that clutching the gear, *X*, to the sprocket disc, *D*, by means of the high-speed clutch, will cause the sprocket to be carried in the reverse direction along with the gear, *X*. It is further evident that re-

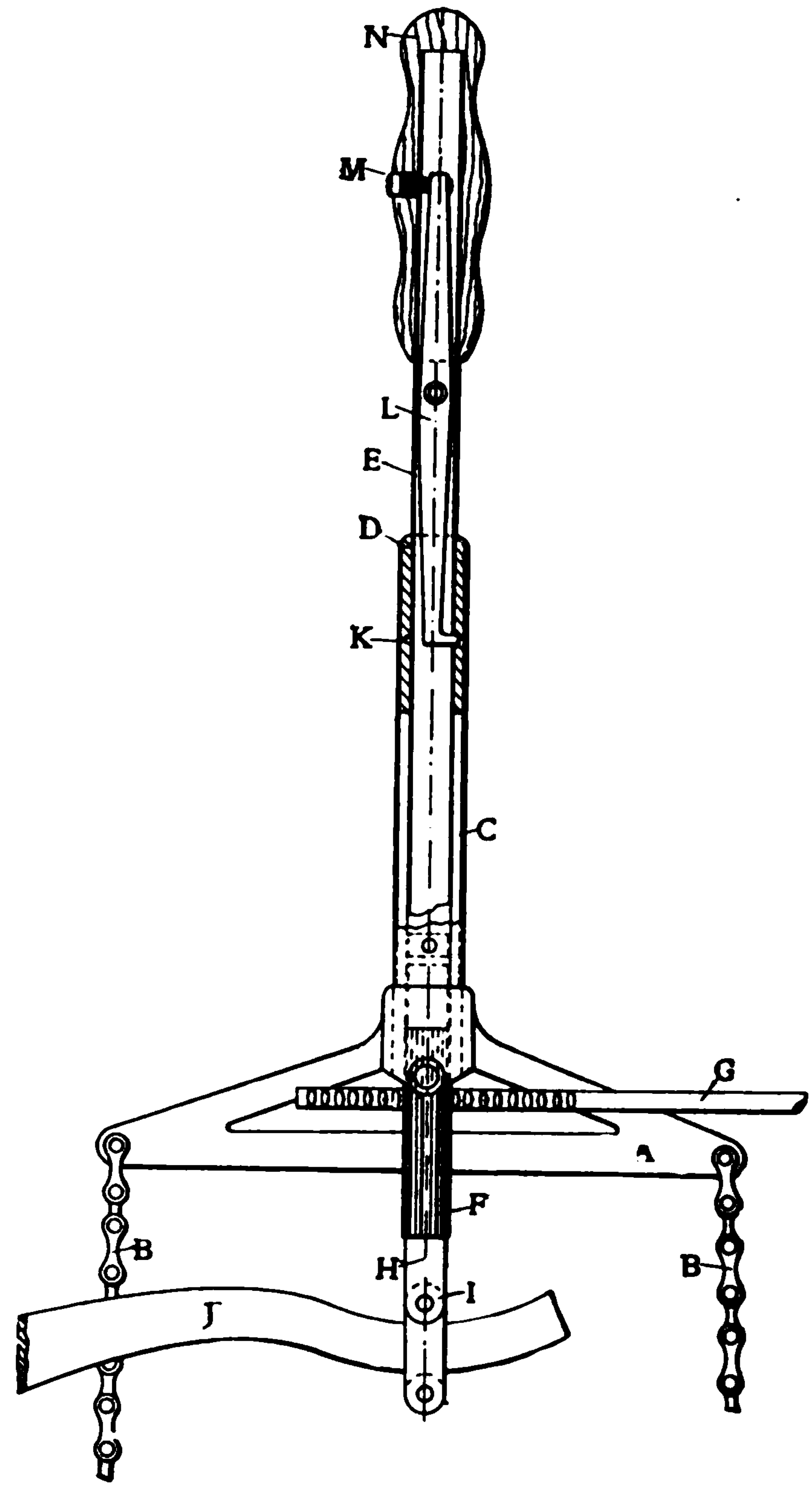



FIG. 272.—Central Control Lever for Steering, Throttling and Operating the Clutches. When arm, J, is raised by an upward movement of handle, N, the low clutch, is set; when depressed, the high clutch is set; in neutral position, both are thrown out. The reverse is operated by a foot pedal.

leasing the high-speed clutch will stop the reverse movement of the sprocket, while releasing the reverse ring, *H*, will permit the pins, *P*, to resume their normal position, under the action of their springs.

The whole device is placed by the side of the motor, on a short extension of the motor shaft, and the power is transmitted from the driving gear, *A*, to the various clutch surfaces, in approximately a single plane, which lessens the torsion strains and gives great strength with little weight. All parts are concentric or balanced, and, therefore, adapted for use at high speeds.

The most interesting feature of this carriage is the single central controlling lever, by which the three different functions of driving the vehicle—steering, throttling and setting the clutches—are easily and readily performed by one hand. It consists of a casting, *A*, pivoted on the forward edge of the seat to swing sidewise. It has oppositely projecting arms below the seat to which the tensile steering connections, *B B*, are attached, while upward and slightly forward the tube or lever proper, *C*, projects. Bushings, *D D*, at each end support a smaller tube, *E*, within the main tube, which smaller tube slides up or down and carries at its lower end a long pinion, *F*. This pinion engages (substantially in the axis of the pivot) a rack, *G*, having diamond shaped teeth which permit the lever to be swung to the extremity of its motion in either direction without damaging the teeth of the rack and permitting the rack to be operated by rotating the pinion, *F*, in any position. This rack is attached near the right-hand side of the wagon, while the other end of the lever operates the throttle slide. The pinion is bored out, and in it is swiveled a stud, *H*, carrying rollers, *I I*, which engage the shifting lever, *J*, so that sliding the internal tube, *E*, up or down carries the shifting lever, *J*, up or down with it, and permits setting the clutches, while in no way interfering with either the steering or the throttling. The end of the shifting lever is bent to the arc described by the rollers in their normal working position, and any slight variations are readily provided for by the hand of the operator. The upper bushing, *D*, on the steering lever is provided with an internal groove, *K*, while the internal tube has in it a lever, *L*, with a projecting end adapted to engage this groove and lock the tube, *E*, in the middle position with the clutches off. By pressing the safety button, *M*, in the handle, *N*, this catch may be disengaged to permit setting either the high or low speed clutches.

This controlling device being centrally placed permits the operator to sit on either side of the vehicle.

**The Haynes-Apperson Transmission Gear.**—The Haynes-Apperson transmission consists of two parallel shafts, *A* and *B*,

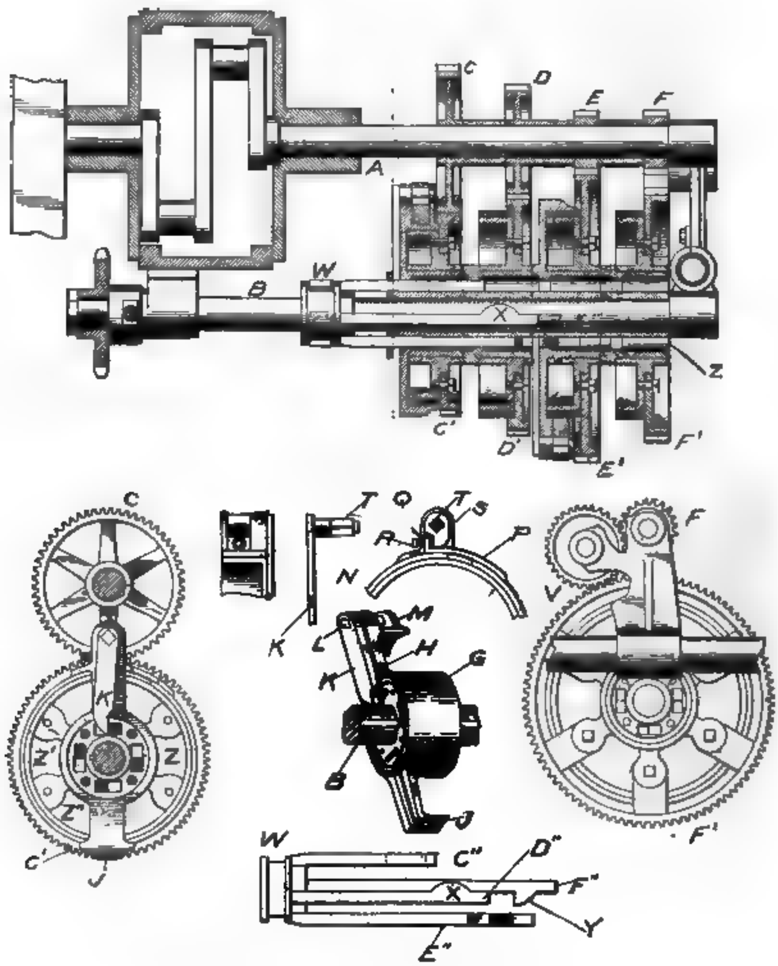



FIG. 273.—The Haynes-Apperson Transmission Gear, shown hung on the crankshaft, as in the lighter cars. The reverse is now accomplished by a chain between F and F', dispensing with the idler, V.

the former being driven direct from the crank, or by belt and pulley from the main shaft, as in the later models of this carriage,

and carrying four gears, *C, D, E* and *F*, keyed in its length. The countershaft, *B*, also carries four loose gears, *C′, D′, E′* and *F′*, each of which is bolted to a band clutch drum, as shown in the figure 273, Each of these brake drums, with its attached gear, turns loose on a separate drum, *G*, which is keyed to the countershaft, all of the attached gears, however, being able to turn through the motion imparted from their mates on the main shaft, without transmitting power to the driving mechanism. As may be readily understood, in order to transmit power through any one of the gears on the countershaft, it is necessary to make it rigid with its drum, *G*. The driving sprocket is keyed to the end of shaft, *B*, as shown.

As will be seen in the separate cut, each one of the drums, *G* carries two arms, *H* and *J*, fixed diametrically opposite one another. On the arm, *H*, is carried a lever arm, *K*, pivoted at *L*, and having a short angle of movement by the attachment of its pivot to the bearings, shown at *M* and *N*. On the two extremities of the arms, *R* and *J*, are carried brackets, which hold the leather brake band against the circumference of the drum turning loose on *G*. One end of this brake band is riveted to the brake on *H*, the other to a forged strap, *P*, having at its extremity the lug, *Q*, through which works the adjusting screw, *R*, whose point bears against the dog, *S*. This dog. *S*, is carried on the square section, *T*, of the shaft attached to the lever arm, *K*, already mentioned; so that a slight movement of the lever, *K*, to the left, is imparted to the dog, *S*, whose point bears against the screw, *R*, on the lug, *Q*; thus drawing the strap, *P*, tight around the drum, which is thereby made rigid with the sleeve, *G*, keyed to the shaft, *B*. By this means the gear attached to that particular drum imparts the motion transmitted to it from its mate on the shaft, *A*, to the countershaft, *B*, such motion varying in speed according to the ratios between the meshed gears. The act of giving the required axial movement to the lever arm, *K*, is performed as follows:

The sleeve, *W*, sliding on the countershaft, *B*, carries four fingers, *C″, D″, E″, F″*, of differing length, as shown in the figures. In the extremity of each of these fingers is a lug, such as is shown at *X* and *Y*, the object of which is to engage the point of the lever, *K*, on some one of the four arms, *H*, thus causing it to move its dog, *S*, and tighten the brake band, as already ex-

plained. In order to accomplish this act without interference, the positions of the levers, *K*, and of the dogs, *S*, differ in each brake drum. On drum, *C'*, for example, it is at the top of the shaft; in *E'* it is at the bottom; while in *D'* and *F'* it is on the right angle in either direction. For this reason, as may be understood from the cut, the four fingers carried on the sleeve, *W*, are similarly disposed, in order that their lugs, *X* or *Y*, may engage the point of the particular lever, *K*, which it is intended to actuate, without interference. In order that the fingers, *K*, may slide through the drums, *G*, keyed to the shaft, *B*, four suitable channels penetrate the entire series of drums, *G*, as shown at *Z* in one of the cuts.

The sliding sleeve, *W*, is shifted by a lever working on the thimble on its outer extremity, and by causing its fingers to penetrate the channels, *Z*, more or less, can give three speeds forward and a reverse. The reverse is accomplished when the lug on the finger, *F''*, engages the lever, *K*, on the sleeve, *G*, belonging to drum and gear, *F'*, which act enables the motion of pinion, *F*, on shaft, *A*, to be transmitted through the idler, *V*, to *F'*, which will of course, rotate in an opposite direction to *F*, thus reversing the motion of the shaft, *B*. In more recent models of this gear, *F* and *F'* are sprockets and are connected by a chain belt, which accomplishes the end of reversing the travel of the carriage to better advantage than by the use of the idler, *V*. The lever operating the speed-changing works through a bell crank to spool, *W*.

**The Winton Transmission Gear.**—The Winton change-speed gear, by the use of three pairs of interlocking spurs and three friction clutches of familiar type, can give two forward speeds and a reverse. The main shaft carries two spur wheels, *A* and *B*, keyed in the positions shown, and a sleeve carrying the sprocket, *C*, and the spur wheel, *D*. The counter-shaft has spur, *L*, keyed to it, and spurs, *K*, and *N*, turning loosely until clutch, *H* or *M*, is thrown in. The main shaft and the sleeve are caused to rotate together through the contact surfaces of the friction clutch, *E*. To obtain the slow speed forward, the clutch, *F*, is thrown on by shifting the thimble, *G*, thus bringing the sleeve, carrying the sprocket, *C*, and the gear, *D*, into operative relations

# CHAPTER THIRTY.

## GENERAL PRINCIPLES OF ELECTRICITY, AS APPLIED TO ELECTRIC VEHICLE CONSTRUCTION.

**The Use of Electric Motors on Vehicles.**—Vehicles propelled by electric motors, whose energy is derived from secondary batteries, are much preferred by many authorities on account of the combined advantages in point of cleanliness, safety and ease of manipulation. When well constructed and well cared for, they are also less liable to get out of order from ordinary causes. Among their disadvantages, however, may be mentioned the facts that the storage batteries must be periodically recharged from some primary electrical source, which fact greatly reduces their sphere of efficient operation. Since at the present time road vehicles driven by electricity are not the prevailing type, power charging stations are few and far between on the ordinary lines of travel, and it is not possible to make a tour of more than twenty-five miles, at the most, from the base of supplies. It is impossible to counteract this deficiency by carrying an extra set of batteries, since these are so immensely heavy, as usually constructed, as to greatly curtail the speed and carrying power of the vehicle. It is also impracticable to propel a vehicle by a battery of primary cells carried within it, since a battery of sufficient power to propel the vehicle would have little, if any, advantage in point of endurance over secondary cells, and when once exhausted must be entirely replaced. One or two attempts to use a primary battery on a motor vehicle have been recorded, but the great waste and expense involved must continue to render such a construction more of a toy and an experiment than a practical possibility. Some machines, particularly of European manufacture, have attempted to combine the use of electricity with the explosive motor, the latter serving the double duty of driving the carriage and charging the batteries, which may then be used to supply energy for the electric motors. It must be said, however, that such a carriage as this is heavy and complicated to a point vastly in excess of the advantages supposedly gained.

**Conditions of Electrical Activity.**—There are two kinds of electricity, according to the usual classification: static electricity and current electricity. As a matter of fact, however, the difference is rather a question of phenomena than of anything more fundamental. The term, static electricity, refers to the phenomena observed in the charging of a condenser, and is attributable to the fact that a body of high electrical potential imparts a portion of its energy to another having a lower potential, just as a heated body gives off a part of its heat to a cold body, equalizing the temperature. The phenomena observed in connection with the electric current differ from the "shock" of the static electricity only in the fact that the current marks a continuous passage of electrical energy from a point of high potential to one of lower potential, showing that the source of E. M. F. is constant, just as a substance in combustion constantly gives off heat. This fact is shown in all types of electrical generators, the galvanic cell operating on the principle that the positive, or high potential, pole constantly transmits its energy along the circuit to the negative, or low potential, pole.

**Units of Electrical Measurement.**—It may be said in a general way that the electric motor has one point of advantage over any heat engine, in the fact that it is much more flexible in operation, which is to say more easily regulated, as to speed and power efficiency. It is also possible to obtain a vastly closer approximation to theoretical requirements under the conditions of practical operation, and to estimate much more precisely the power efficiency to be obtained from a given electrical source on any given circuit. This is because the available working energy, in terms of amperes, is in exact proportion to the voltage and resistance of the circuit, as well as to the amount of efficient activity in terms of work accomplished and time consumed. As we have already seen, the power efficiency of a steam engine is estimated, in the first place, in terms of heat and power units; secondly, in terms of foot-pounds or the efficiency of the engine to move so many pounds through such a space in such a length of time; and thirdly, in terms of gauge pressure or estimated temperature. In short, the units of power are all stated in terms of pounds, feet and seconds in estimating the power passed on any given electrical circuit. The units of electrical measurement are stated

in terms of length, weight and time, which is to say in terms of centimeters, grams and seconds. This gives the C. G. S. units, as they are called, which are estimated in accordance with the decimal system of measures. The units thus established are, of course, largely arbitrary—just as are all units—but they have been carefully estimated, so that the proportions between current strength, circuit resistance and voltage may be accurately maintained.

**The Ohm, the Unit of Resistance.**—The first unit of electrical measurement with which we have to deal is the ohm, which is the unit of resistance. This unit measures not only the relative resistance of a circuit composed of a conducting wire of a given length and diameter, as compared with wires of different length and diameter composed of the same material, but also the specific resistance, or resistivity, which refers to the immense variations in resisting quality found between given wires of the same length and cross-section, made of different materials. The different resistivity of several different metals, as found in circuits, precisely similar in all points of dimensions, is demonstrated in the fact that, while a unit wire of silver shows a conductivity of 100, and one of copper, 99, a wire of iron gives only 16.80

The value of the ohm, as fixed by the Electrical Congress, at the Columbian Exposition in 1893, is equivalent to the resistance offered to one volt of E. M. F. by a column of mercury 106.3 centimeters in height (about 41.3 inches), and one square millemeter (.00155 square inch) cross-section, determined at the temperature of melting ice (39° Fahrenheit). Mercury was chosen for this test, because on the scale giving a conductivity of 100 to silver, it stands 1.6, while its resistivity is 99.7, as compared with 1.52 for silver; being thus very nearly unity in the first particular, and 100 in the second. One ohm is also equivalent to the resistance to be encountered in one foot of No. 40 B. & S. copper wire, which has a diameter of .003145 inch, or 3.145 mils; or to the resistance encountered in about two miles of the copper wire used in electric trolley lines. In both cases we have approximately the equivalent of the afore-mentioned column of mercury, if the test is made at a temperature of 45° Fahrenheit. In general, the resistance of a circuit varies inversely as the diameter of the wire, and directly as the length of the wire.

**The Ampere, the Unit of Current.**—The unit of electrical current is called the ampere, which has been authoritatively fixed as the equivalent of the current strength, which can deposit .00033 grams of metallic copper, by the electro-plating process, in each second of time. In this respect it measures not only the current intensity, or available working energy, but also the rapid-

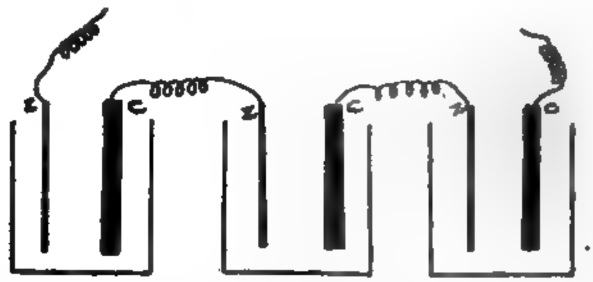



FIG. 276.—Diagram of a Series Circuit, showing Three Galvanic Cells in Battery. As shown, the copper, or positive, pole of the first cell is connected to the zinc, or negative pole of the second, and so on, leaving a negative terminal at one end and a positive at the other. Thus the current emerging from each cell passes through all those succeeding in line, the total voltage of the battery being equivalent to the sum of the individual voltages of the several cells. If, on the other hand, several motors, or other electrically affected apparatus, be connected in series, the result is to increase the "back pressure" (C E. M. F.) on the same ratio, and hence cut down the operative efficiency of each.

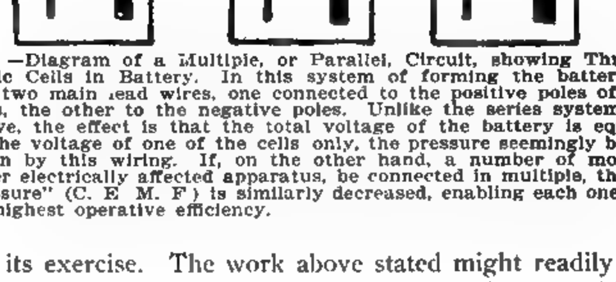



FIG. 277 —Diagram of a Multiple, or Parallel, Circuit, showing Three Galvanic Cells in Battery. In this system of forming the battery there are two main lead wires, one connected to the positive poles of all the cells, the other to the negative poles. Unlike the series system shown above, the effect is that the total voltage of the battery is equivalent to the voltage of one of the cells only, the pressure seemingly being cut down by this wiring. If, on the other hand, a number of motors, or other electrically affected apparatus, be connected in multiple, the "back pressure" (C. E M. F) is similarly decreased, enabling each one to give its highest operative efficiency.

ity of its exercise. The work above stated might readily be accomplished by a given current in ten seconds, instead of in one, but such a current would not have the value of one ampere, only of 1-10 ampere—since it required ten times as long to accomplish the result.

Another frequently mentioned analogy for the ampere is the so-called miner's inch, which represents the product of an orifice one inch square, through which water is allowed to escape from a given tank or flume, by the height of the column of water in the tank, in inches. The miner's inch, is, therefore, in the first place, a measure of rate or velocity, giving inch-seconds, in fact, or the number of cubic inches of water passed in each second of time. Thus, while water flows at the rate of so many miner's inches, the electrical current flows at the rate of so many amperes; the rate per second, in both cases, being directly relative to the original pressure of energy at the source. Thus, it is inaccurate to speak of an ampere per second, since such an expression means simply a current of one ampere; thus also, in speaking of a current of ten amperes, for example, we do not refer to the amount of current passed in ten seconds, but to that passing in one second. There is, however, a unit of electrical measurement, which is called the coulomb, or ampere-second, which is the measure of electrical quantity, being equivalent to the product of the amperage of the current by the number of seconds it has been flowing.

**The Volt, the Unit of Pressure.**—Having determined the value of the resistance unit and current unit, it is a simple matter to determine the voltage produced by an electrical source. One volt E. M. F. can produce a current of one ampere on a circuit having a resistance of one ohm. There are several specified equivalents for estimating the exact value of one volt E. M. F., but these usually refer to the determined capacity of some given type of galvanic cell. It is sufficient to say, however, for ordinary purposes, the majority of commercial chemical cells are constructed to yield approximately one volt. The ordinary Daniell cell used in telegraphy has a capacity of 1.08 volt, and the common type of Leclanché cell gives about 1.50.

**Ohm's Law of Electrical Circuit.**—The value of the volt, as just given, which is to say, the amount of E. M. F. able to produce a current of one ampere through the resistance of one ohm, gives us a very good general statement of the fundamental principle of electrical science, which is popularly known as Ohm's Law. This is a law of proportions between the three factors in

the production of electrical energy, by which any one of them, as well as the total power efficiency of the circuit, may be readily determined.

Ohm's Law may be specifically stated under six heads, as follows:

(1) The current is in direct proportion to the electromotive force, and in inverse proportion to the resistance.

(2) The current is equal to the electromotive force, divided by the resistance.

(3) The resistance varies directly with the electromotive force, and inversely with the current; hence,

(4) The resistance is equal to the electromotive force, divided by the current.

(5) The electromotive force varies directly with the current and with the resistance; hence,

(6) The electromotive force is equal to the current multiplied by the resistance.

As may be readily understood, however, all these various rules are merely so many different ways of stating the proposition involved in the first, which is, in fact, simply equivalent to that involved in the definition of the ohm already given.

**The Watt, the Unit of Activity.**—Having stated the law of proportions between the various component elements of a live circuit, we may readily see that the unit of active work performed by the current must stand in some determinable proportion to the other elements. Accordingly, we find that the unit of electrical activity, which is known as the watt, and which represents the rate of energy of one ampere of current under a pressure of one volt, is equivalent to the product of the voltage by the ampereage.

Other equivalents of the watt make it equal to the product of the resistance by the square of the current, or the quotient of the square of the voltage by the resistance. Thus, a current of ten amperes at a pressure of 2,000 volts will develop 20,000 watts, as will also another given current of 400 amperes at fifty volts.

The operative capacity of an electrical motor is usually stated in terms of watts, or kilowatts (1,000 watts), which may be reduced to horse-power equivalents by dividing by 746, which figure indicates the number of watts to an electrical horse power.

# CHAPTER THIRTY-ONE.

## ELECTRICAL GAUGES—VOLTMETERS AND AMMETERS.

**Electricity Meters.**—The electrical gauges, ammeters and voltmeters, used on automobiles are constructed on the principle of the D'Arsonval galvanometer, with either a permanent or a variable field. With several of the more prominent manufacturers the former construction seems to be the one most approved. The general features are a small oscillating solenoid whose core is mounted on jeweled bearings, arranged like a dynamo armature between the poles of the permanent horseshoe magnet, with a hand or pointer pivoted at the bearing, so as to indicate the variation in electrical conditions on a graduated scale. A coiled steel spring attached at the base of the needle acts to restrain and control its movements, thus ensuring reliable indications of current strength or intensity.

**Construction of the Volt-Ammeter.**—The permanent magnets used on such instruments are of a special quality of hardened steel, magnetized to a point somewhat below the full magnetic capacity of the metal, and possessed of great permanence. The pole pieces of soft steel are firmly secured to the feet of the magnet, the joint being ground and intended to be permanent. The core of the coil is arranged to render uniform the field in which its coil oscillates, and over it are wound two layers of insulated wire—the first short-circuited on itself, for the purpose of "damping the movement of the coil by the generation of eddy currents within it, thus rendering the instrument a periodic, or dead-beat, in its indicatons." Above this short-circuited layer, and at right angles to its direction is wound the "active coil," consisting of a number of turns of fine copper wire, to which current is conveyed through the medium of the controlling springs at either end of the core spindle. The principal difference between the voltmeter and the ammeter is that in the former the active coil is in series with a resistance, and in the latter is connected across the terminals of a shunt block. The metal used in these

resistance and shunts is an alloy having a temperature co-efficient of about .001 at 100° Centigrade. The voltmeter is, thus, really an ammeter; the resistance serving to keep the amperage in step with the voltage.

**The Indicator Hand.**—The pointer hand in such instruments is a rod of hardened aluminum wire, formed up with an eye for attachment to the axis of the core, and a counterpoise, shown in

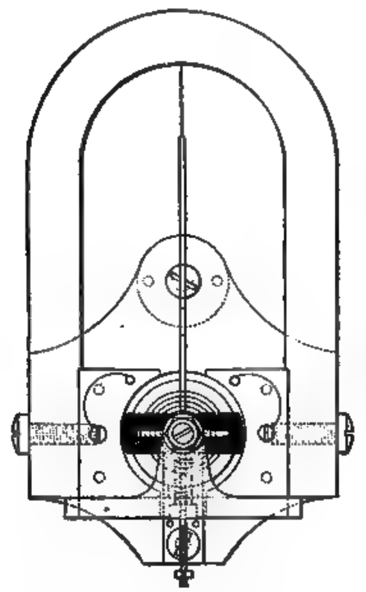


FIG. 278.

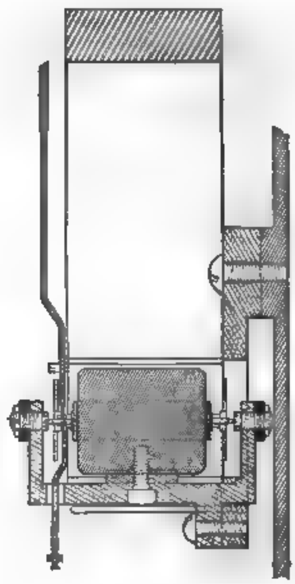


FIG. 279.

FIGS. 278 and 279.—Sectional Diagrams Illustrating the Construction of Volt and Ammeters. The iron core is secured to the base plate by a screw. The active coil is shown wound around it from end to end.

the diagrams, at the opposite end of the wire. The whole instrument is rigidly mounted on a cast brass bracket, which serves the double purpose of ensuring perfect rigidity and freedom from warping, etc., and enables the removal of the moving parts without disturbing the pole pieces.

**Forms of Volt-Ammeter.**—For automobile use a voltmeter and an ammeter are usually mounted on one base, with their

graduated scale cards sufficiently near together to enable rapid reading of battery conditions. After slight practice the driver of an electric carriage can easily keep himself informed on the amount of current actually being used and on the probable duration of the charge. He can also learn to know the point of full charge, when his battery is connected to the generator. These instruments frequently have the scale traced on opalescent glass, so as to be illuminated at night by an incandescent lamp placed behind it. As shown by the accompanying cuts, the volt-ammeters made by different manufacturers vary in appearance—one type having the two scales arranged side by side, another, end to end. The voltmeter indicates the pressure between bat-

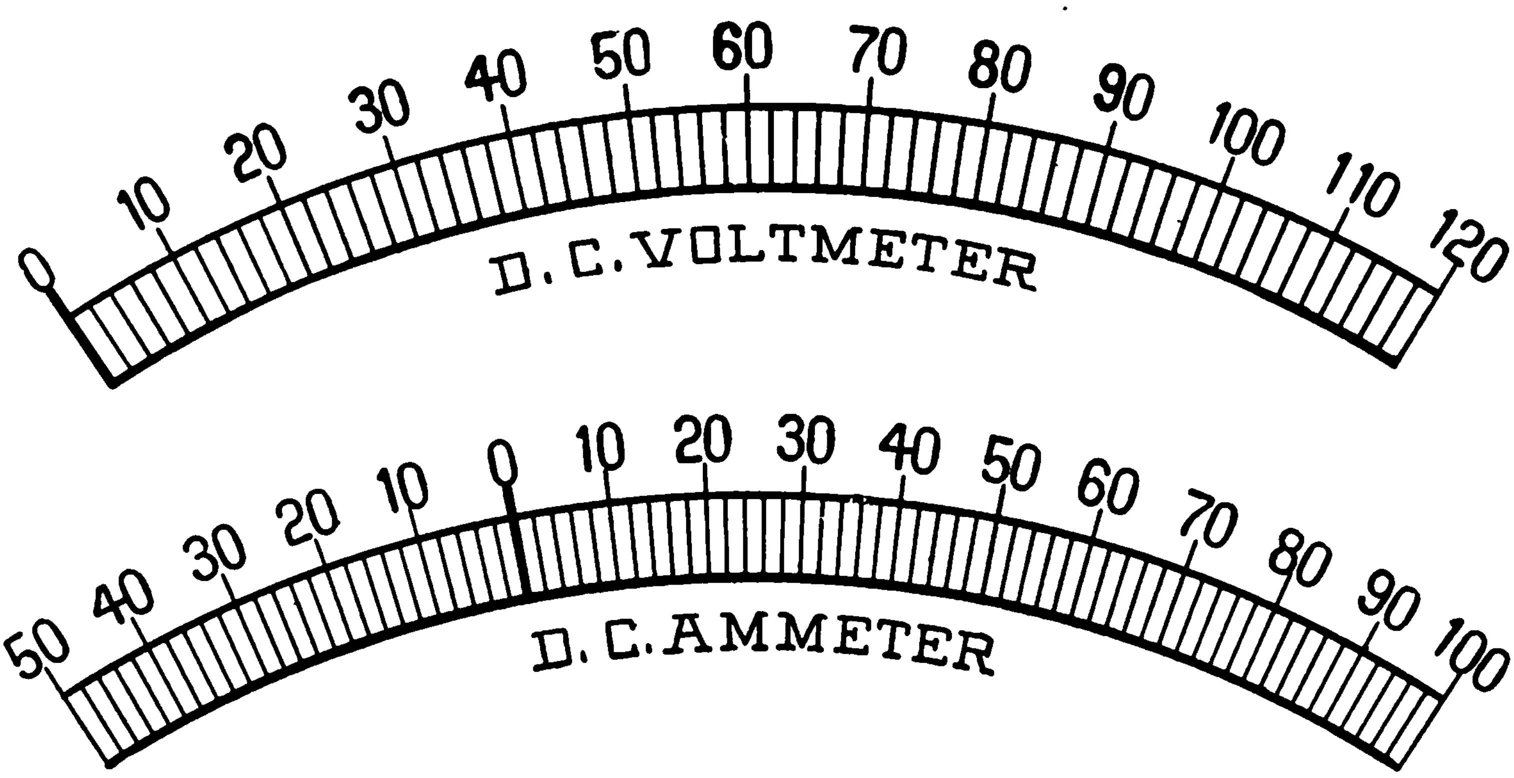



FIG. 280.—Index Scales of a Voltmeter and an Ammeter for Measuring the Pressure and Intensity on a Direct-current Electrical Circuit.

tery terminals, both in charging and discharging, while, in the ammeter scale, the space to the left indicates the amperage of the charging current, and that to the right, the amperage of the charging current are both in proportion to the discharge capacity of the battery, it is a simple matter to adjust the charging by the volt-ammeter readings, to suit the directions regarding the particular make of battery in use. As a general rule, storage batteries are constructed to give their highest discharge rate at the eight-hour discharge. Consequently, its capacity is rated at 40 ampere-hours, and the normal charging current is given as one-eighth of its ampere-hour rating, or as the equivalent of its

largest rate of discharge per hour. In this case, accordingly, the normal charging rate would be 5 amperes, and the current may be adjusted by the rheostat until the indicator hand points to 5 on the left-hand portion of the ammeter scale. If, however, the charging is to be done in shorter time than normal the amperage may be periodically adjusted to suit directions. The battery having a normal charged capacity of two volts per cell, is seldom charged above 2.6 volts, on the average, and never discharged below 1.75 volts per cell. Consequently, since the battery is always charged in series, the use of pressure is constantly indicated by the voltmeter needle, which registers the total voltage of the battery at all times in the charge. In discharging, it

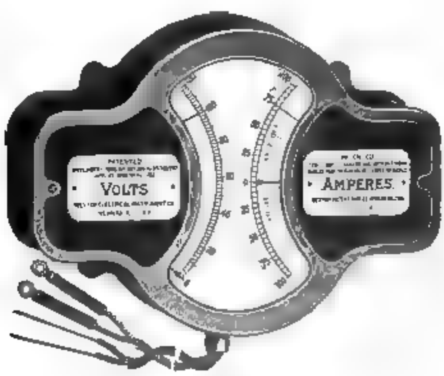



FIG. 281.—Weston Volt-ammeter of the Type used on Electric Vehicles. Other makes of these instruments have the index scales side by side, instead of end to end.

indicates the voltage of the couple in circuit, whether the battery unit be connected in multiple, series-multiple, or series; showing for a 4-unit 40-cell battery, 20, 40 and 80 volts, respectively.

**Reading Speed and Power Output.**—In running the vehicle the voltmeter scale reading indicates the amount of charge still remaining in the battery—the difference between 1.75 and 2.6—and the ammeter rate at which it is being used. If the speed of a vehicle on a hard level road be determined and the reading noted in connection with it, the ammeter may be used as a very good speed indicator for operation under similar conditions.

The ammeter also indicates an overload, which, if above a definite specified figure, would likely damage the battery, as when attempting to start with brakes set, or in beginning the ascent of a heavy grade from a standstill. The amount of power being consumed by the motor is, of course, always the product of the volts by the amperes. Thus, with readings of 80 volts and 16 amperes, 1,280, or about 1.7 horse-power, are being constantly used.

**Voltmeter Indications.**—Although the voltmeter should always register between 1.75 and 2.6 per cell, the former figure indicating the point of discharge—it may happen that an unusually hard road will bring the needle temporarily below that point. Such indication does not of necessity mean that the battery is exhausted, as on coming upon a better road, it will quickly resume its normal reading.

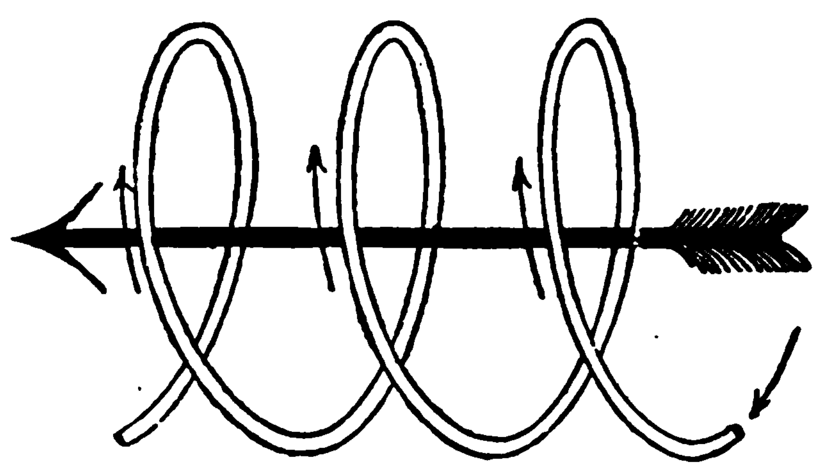


Fig. 282.—Diagram Illustrating the Directions of the Current in the Field Windings and the Induced Current, as found in magnets, solenoids and dynamo operation.

## CHAPTER THIRTY-TWO.

### THE CONSTRUCTION OF THE DYNAMO ELECTRICAL GENERATOR AND THE ELECTRICAL MOTOR.

**Electrical Induction.**—Electrical induction, as manifested in its simplest form, has been repeatedly demonstrated by two contiguous circuits of wire, the one containing an electric battery or other source of current, together with a switch for alternately opening and closing the circuit as desired; the other circuit of wire containing no battery or other source of current, but having its terminals connected to a galvanometer. If, now, we close the first circuit, allowing the current to flow from the electrical source, we will observe, as indicated by the galvanometer, that a current of somewhat less strength is flowing in the other circuit, in an opposite direction. This induced current, however, is only momentary, continuing only long enough to allow its strength and direction to be recorded. On opening the circuit, including the battery, thus cutting off the current, we again notice, as recorded by the galvanometer, that a current, weaker than the first one observed, is flowing in the second circuit in the same direction as that which has just been cut off in the first. This current is also momentary.

In regard to this phenomenon, several principles may be stated:

(1) Increasing the strength of the current in circuit 1 increases the strength of the momentary current in circuit 2.

(2) Decreasing or cutting off the current in circuit 1 decreases the strength of the current in circuit 2, also causing it to flow in the same direction as the current in circuit 1.

(3) If we move the current-carrying wire of circuit 1 nearer to the wire of circuit 2, we will find that a strong current is induced in circuit 2, which moves in a direction opposite to that in circuit 1. If we move the wire in circuit 1 further from the wire in circuit 2, we find that a weaker current is induced in circuit 2, moving in the same direction as that in circuit 1.

(4) If the wire used in circuit 1 is of low resistance and that used in circuit 2 is of high resistance, the current induced in cir-

cuit 2 will show a greater electromotive force than that flowing in circuit 1. Conversely, if the wire used in circuit 1 be of higher resistance than that used in circuit 2, the current induced in circuit 2 will show a lower electromotive force than that flowing in circuit 1.

**The Production of Magnets.**—The most familiar operation of current induction is seen in the production of an electro magnet, which consists of a core of soft iron wound about with a certain length of insulated wire, preferably copper, on account of its high conductivity. As soon as a current is sent through the wire

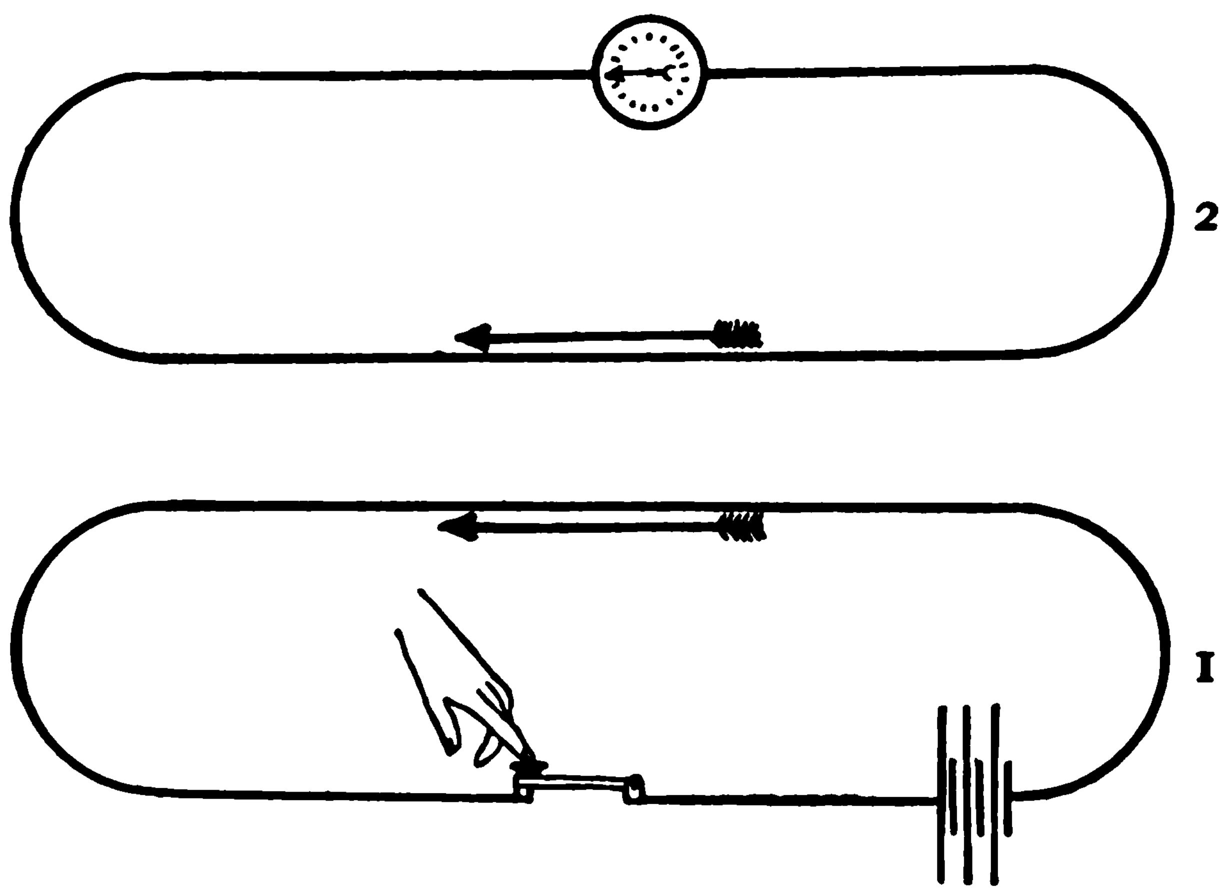



FIG. 283.—Diagram Illustrating the Action of Voltaic Induction Between Two Circuits: the one including a source of electrical energy and a switch; the other including a galvanometer, but having no cell or other electrical source. The direction of the battery current in circuit 1 is indicated by the arrow; the arrow in circuit 2 showing the direction of the induced current.

coiled about the iron core, its effects are seen in the fact that the core becomes magnetic, attracting iron and steel bodies, and in general exerting an observable effect upon any polarized conductor, such as a solenoid. As soon as the current in the insulated winding is cut off, the iron core loses its magnetic properties. If, however, a core of hardened steel be similarly wound with insulated wire, and a strong current be sent through it, the result will be that the steel will become a permanent magnet,

which is able to exert the characteristic magnetic effects for a practically indefinite period.

A bar of iron or steel thus temporarily or permanently magnetized invariably shows the phenomenon of polarity, manifested in the first place by the ability to attract the unlike poles and repel the like poles of another magnet, the poles being always determined as positive or negative by the points of the inlet or exit of the current, as in the case of solenoids. The magnet can also induce a momentary current in a closed circuit of wire in exactly the same fashion just described in connection with the ordinary action of current induction. These simple experiments demonstrate the fact that between the poles of any magnet there is a continual operation of force, the lines and activity of which may be shown by scattering iron filings on and between the two extremities. These iron filings, if allowed to adjust themselves, in obedience to the magnetic force exerted upon them, will be found to be thickest at the points nearest the extremities of the poles, and lightest at the points furthest from the extremities, in the latter positions describing arcs of circles, thus showing the strength and direction of the force acting upon them. Further, the intensity of the magnetic force is shown to be greatest when the two poles are connected by a piece of iron or steel, known as an armature, this being efficient in prolonging the magnetic activity of a permanent magnet, and preventing the dissipation of the magnetic force through a much longer period.

**Electrical Dynamos and Motors.**—The machines for converting mechanical movement into electrical current, and for converting electrical current into mechanical movement, in other words, the dynamo generator and the electric motor, respectively, are the same so far as the general features of their construction are concerned. In operation, however, the motor is the exact reverse of the dynamo. As just stated, the theory of electrical generation by mechanical means is that the lines of force of a magnet should be cut through, so that their strength and direction at any point or at any time should be made to vary constantly. In addition to this, it is necessary that there should be some means of collecting the current, resulting from the continual disturbance of the magnetic field, and supplying it to a circuit.

**The Operative Principles of a Dynamo.**—In order to review the principles involved in both the generation and mechanical utilization of the electrical current, it will be necessary briefly to enter into somewhat rudimentary principles. In an accompanying cut may be seen a diagram representing the simplest conceivable dynamo electric generator. As may be seen, the spindle, *A*, rotates between the two poles, *N* and *S*, of the magnet. Upon this spindle, *A*, is carried a loop of wire, the two terminals of which are connected to the two drums carried on the forward end of *A*. The metal of these drums, as indicated in the cut, is insulated from *A*, so that all the electric current generated by the machine may be taken up by the brushes, $B^1$, $B^2$. It is obvious that, when the spindle, *A*, is rotated in the direction of the arrow at the top of the cut, the double loop, *CC*, will cut through the lines of force, indicated by the dotted lines between *N* and *S*. Since, therefore, these lines of force have a more direct path between the two poles, when the loop, *CC*, is in a horizontal position than when it is in a vertical position, as shown in the cut, it follows that the momentary current induced in the circuit formed by brush, $B^1$, loop *C*, brush, $B^2$, and the outside circuit wire, *E*, connecting the two brushes, will constantly vary in strength, and also in direction of movement, as the two parts of the loop are moved towards and from the poles, *N* and *S*. Since the direction of the current must constantly fluctuate with the movement of the armature loops, *CC*, it follows that the current delivered to the outside circuit, *E*, through the two brushes, will be an alternating current, which is to say, one flowing first in one direction and then in another, the potential varying with the direction of flow. In order to make the current flow constantly in one direction, it is necessary to use a collector or commutator, the construction of which will be explained in place. Without this all dynamo currents would be alternating.

The armature of a practical dynamo or motor differs from the simple loop shown in the figure just mentioned, principally in the fact that a large number of such loops are mounted on a single rotating spindle, so that the magnetic lines of force are cut through a correspondingly larger number of times in a given period, with the result that the poles are shifted at a much higher frequency, and the alternations of the produced current are much more rapid.

**The Essential Parts of Dynamos and Motors.**—The essential parts of a dynamo generator and also of an electric motor are:

(1) The field magnets constructed like ordinary electro magnets, and having two or any even number of opposed poles with their windings connected in series.

(2) The armature rotating between the fields, so as to cut the lines of magnetic force.

(3) The pole pieces, which are the exposed ends of the magnet cores.

(4) The commutator or collector.

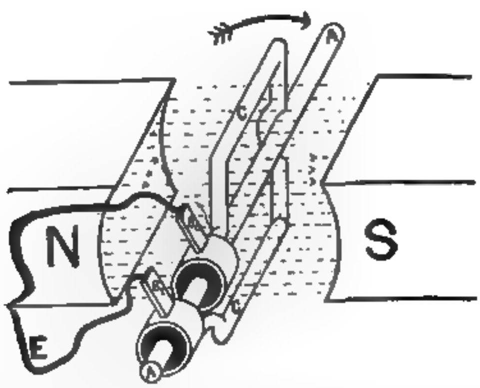



FIG. 284.-Diagram of a Dynamo Electrical Generator, arranged for producing an alternating current, showing the constructional and operative features. Here N and S are the positive and negative poles of the field magnets, between which the lines of force are shown by the dotted lines. A is the armature spindle; $B^1$ and $B^2$, the brushes bearing on the ring drums. C, the coil, or winding, of the armature; E, the outside circuit to which the current is supplied.

(5) The brushes which rest upon the cylindrical surfaces of the commutator, and as the terminals of the outside circuit, take up and deliver the current generated in the coils of the armature.

**The Varieties of Dynamo-Generators.**—There are a number of species of dynamo, discriminated according to the use for which they are intended, the arrangement of the armatures, the winding of the field magnets, and the kind of current they are intended to produce. For general purposes, however, we may discriminate three familiar forms of dynamo, according to the system adopted in the winding of the field magnets; these are:

(1) Series-wound dynamos, in which the two poles of the mag-

net are wound with a few turns of a heavy low resistance wire, one terminal of which is connected to one of the brushes, moving thence entirely around both pole cores, thence to the outside line and back through the other brush.

(2) Shunt-wound dynamos are wound in the same fashion as the series-wound, with the exception that the pole cores are wound with a large number of turns of high resistance wire, the field windings, however, forming a shunt-circuit from the main outside circuit, which has its terminals at the two brushes bearing on the armature. The terminals of the field magnets are also connected to the brushes.

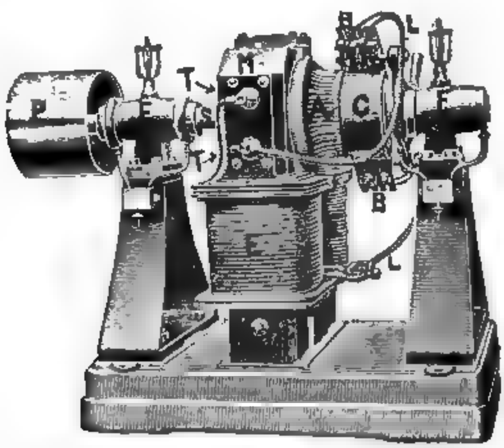



FIG. 285.—A Typical Dynamo-Electrical Generator, with parts lettered. A, the armature, B, B, the brushes; C, the commutator; E, E, the windings of the field magnets; M, the pole piece of the salient field magnet; F, F, bearings of the armature spindle; L, L, the lead wires; P, the pulley, T, T, terminal connections of the outside circuit.

(3) Compound-wound dynamos combine the features of both the series and shunt-wound machines, having the field magnets double-wound with (a) a few turns of heavy low resistance insulated wire connected to circuit as in the series-wound dynamos, and (b) a second winding arranged precisely as in a shunt-wound dynamo.

**Shunted Field Windings, Their Use.**—The object of using a shunted circuit for the windings of field magnets is that the machine may more readily excite its own fields at starting, and that

the current may be produced before the rotating armature has fully taken up its speed. Some dynamos have their fields excited by a separate source of electrical energy, in which case the magnet windings are not connected to the brushes' ends, on the armature, but direct to the terminals of the outside source of electrical energy. As a usual thing, however, it is unnecessary to use a separate source of current, for exciting the magnetic fields, since there is a sufficient amount of residual magnetism, acting between the poles of the magnets, to start the generation of electrical energy, as soon as the armature begins to rotate.

**Residual Magnetism and Current Generation.**—This residual magnetism, which is a familiar property of an electro magnet, that has once been magnetized, of course, has very weak lines of force at the beginning of the rotation, but these weak lines, being cut through by the coils of the armature, are able to produce a small amount of E. M. F., which sends a minute current through the windings of the field magnets, in consequence of which both the E. M. F. and the field currents are constantly increased until the rotation of the armature has reached its maximum speed. At this point, also, the output of the electrical energy has attained its highest point.

**Construction of a Practical Armature.**—The armature of a dynamo or motor consists of a drum or ring forming a core and support, upon which a number of coils of insulated copper wire are wound in the same general fashion as has been shown in connection with the ideal simple dynamo already mentioned. The drum or ring forming the supporting core is attached to the rotating spindle by a spider or key. The latter attachment is universally used with drum armatures. The most usual method of constructing armature cores for dynamos is to build them up by placing together, face to face, a number of thin discs of soft sheet iron, which are insulated one from the other by suitable varnish or enamel. The circumference of each of these discs is toothed or serrated, so that when a number of them are placed together the cylindrical armature body has a corresponding number of deep grooves running in its length. Into these grooves the insulated wire of the winding is inserted. The greater the number of the teeth in the circumference of the arma-

ture drum, the smaller the danger involved in the production of eddy currents, which are a troublesome source of overheating and other derangements of the machine. It is essential that the cores of the rotating armature should be composed of the softest iron in order that the greatest magnetic permeability may be obtained, since the body of the armature forms an integral part of the circulation.

**The Commutator and Its Use.**—The commutator of the dynamo or motor is one of the most essential elements in the generation and use of the current. Its function is to collect the current produced by the cutting of the lines of magnetic force, so as to cause them all to concur to a desired result, transforming what would naturally be an alternating current into a direct current. As usually constructed, the commutator consists of a number of L-shaped metal pieces, which are so formed that when one arm of each piece is connected to the insulating disc at the end of the armature drum, the other arm will constitute one segment of the cylinder arranged around the armature spindle. In general, the commutator is formed of alternating sections of conducting and non-conducting material, running lengthwise to the axis, upon which it turns. Each segment, as we have already seen, constitutes the point of connection between two sections of the armature winding; it is thus possible to collect the currents induced in the winding at the desired point, for although the effect of the magnetic induction upon the windings of the armature naturally tend to produce an alternating current, as already suggested, there are, as will be subsequently explained, certain points in the rotation of the armature at which the induced currents invariably move in one direction, owing to the permanence of the magnetic conditions at those points. These points are known as the neutral points, or points of commutation, and in order that the direction of the current sent over the outside circuit may be perfectly constant, the brushes which form the terminals of that circuit are here placed upon the commutator. In other words, the brushes are so arranged that they will bear upon the conducting segment of the commutator at exactly the neutral point in the rotation of the armature. These neutral lines are situated at either extremity of its determined diameter of commutation, which diameter is theoretically at right angles to the

direction of the magnetic lines of force, as estimated for a two-pole magnet, and would be in that position practically but for the magnetic lag, which slightly varies the angle. The number of segmental bars on the cylindrical end of the commutator is naturally dependent upon the scheme of winding adopted on the armature, and the number of sections into which it is grouped. In general, an increase in the number of segmental bars diminishes the tendency to spark and lessens the fluctuations of the current. The increase in the number of bars, however, has fixed limits for several reasons. In the first place, principally in large machines, a great increase in the number of bars has a tendency to increase the voltage of the dynamo beyond the safe limit. In smaller dynamos, trouble speedily arises from the fact that each bar becomes so thin that a brush of proper thickness to collect the current would lap or bridge over more than two of them at once.

## CHAPTER THIRTY-THREE.

### THE OPERATION OF ELECTRICAL GENERATORS AND MOTORS.

**Conditions of Dynamo Operation.**—The dynamo electrical generator is a very sensitive and delicately organized machine, demanding for its efficient operation perfect adjustment of its various parts and a constant watchfulness for any symptoms of dynamo disease, overheating or sparking, or any of the results usually following imperfect adjustment or careless handling. These conditions, however, need not be enlarged upon here, since we are concerned only with the essentials of construction alike to the dynamos and motors, and with the general principles upon which the generation and use of the electrical current depend.

As already stated, the operation of a self-excited dynamo is largely indicative of the principles upon which it operates: The cutting of the lines of the residual magnetism between the cores of the field magnets, the production of induced currents in the coils of the armature, and their transmission through the circuit of the field magnet windings, where they are efficient in increasing the magnetism of the cores, also the E. M. F. output of the machine, as the rotation of the armature approaches the maximum speed.

**The Polarization of the Armature.**—The usual rule applying to the efficient operation of a dynamo is that the E. M. F. produced is in proportion to the number of turns of wire wound about the armature, and within definite limits also to the speed of its rotation. The result of the rotation of the dynamo armature is to produce a number of reactions between its windings and the magnetic field, with the result that the armature itself becomes a magnet, being constantly polarized at certain definite points in its path of rotation. According to the accepted rule of magnetic induction, the tendency is to produce poles in the armature at right angles to the lines of force, but since the neutral points, theoretically situated on the same diameter, are points of contact between the brushes and the commutator, where the cur-

rent leaves and re-enters the winding of the armature, it will be found that the armature is really transformed into two separate adjacent magnets, having two north and two south poles, on either side of the diameter of commutation. These double poles, practically operating as a single pole, at the two extremities of the given diameter, act to produce the great distortion of the lines of magnetic force, which follow the rotation of the armature. As shown in an accompanying diagram, these lines of force are twisted into an oblique direction. This result is largely due to the fact that the polarity of the armature is not symmetrical with that of the field magnets. Were the brushes placed at any other point than the extremities of the diameter of commu-

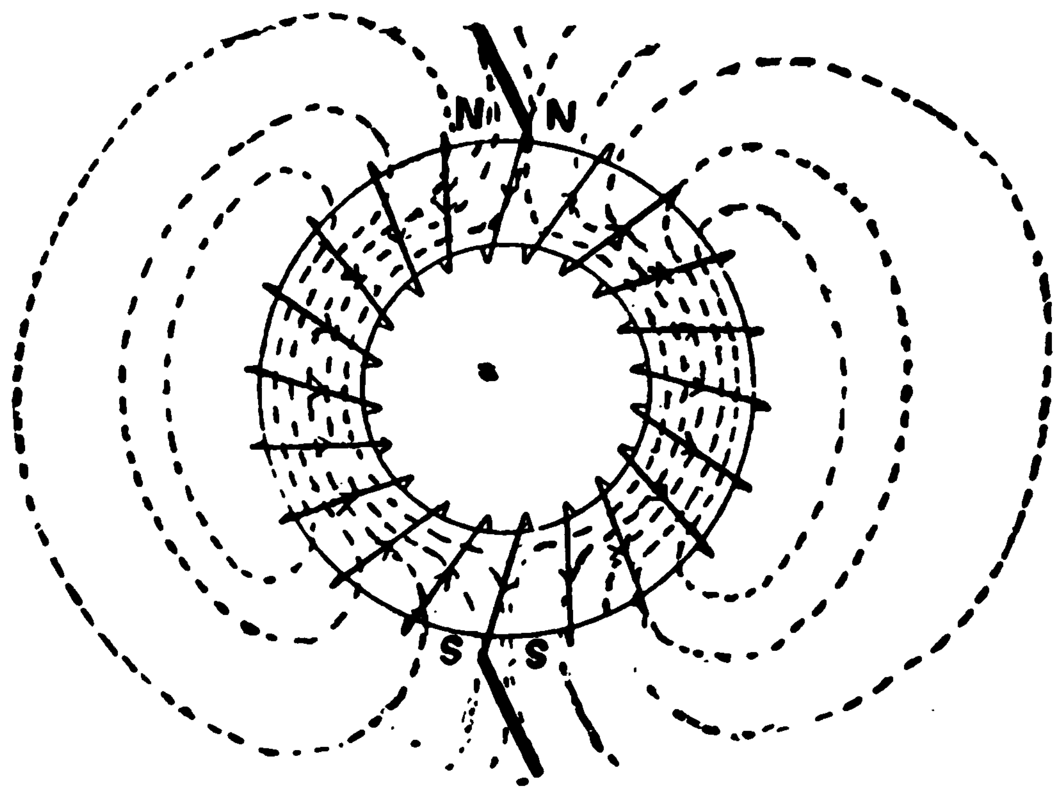



FIG. 286.—Diagram of the Polarization of a Rotating Dynamo Armature of the Ring Type, showing directions of the lines of force and of the induced current.

tation, the result would be short-circuiting of the armature coil. This distortion of the magnetic field, which is an important agent in the production of the current, must be regarded as the resultant of the two induced polarities of the armature, one of which is due to induction from the field; the other to induction from its own windings. It marks the fact that, in the process of shifting the neutral points as the armature rotates, the induced polarities are continued, with decreasing effect to be sure, hence continuing to exert an attractive or repelling reaction upon the field magnets.

As shown in an accompanying figure showing the polarization of the rotating armature, it will be seen that the current pro-

duced in the armature windings are moving in two different directions between the contacts of the brushes. Entering at the north poles of the armature, their direction is through the windings, down either side to their exit at the south poles. These two oppositely moving currents, flowing between the north and south poles of the armature, which is to say between the negative and positive brushes, respectively, act upon the body of the armature after the manner of a current flowing in the windings of an electro magnet, or through the helical portion of a solenoid. The result is that an induced current is set up in the armature itself, which, according to the rule above-mentioned, moves at right angles to the direction of the inducing current in the windings.

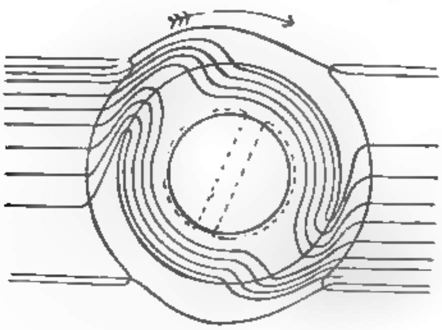


FIG. 287.—Diagram of the Distortion of the Lines of Magnetic Force as they pass through the Body of a Rotating Dynamo Armature.

**Principles of Electrical Motor Operation.**—The foregoing discussion of the dynamo electrical generator is included in this work, in order to prepare the reader for a better understanding of the electrical motor, for, as already stated, the electrical motor is the exact opposite of the dynamo in all matters touching its practical operation. This means that a typical dynamo may be run as a motor, with no other alterations than changing the position of the brushes to the negative lead.

The respective action of a motor and a dynamo may be understood from an accompanying diagram. It shows a dynamo and a motor coupled together, so that the current generated in the former is driving the latter. As will be seen, both the dynamo and the motor are rotating right-handedly, thus generating an

electromotive force, tending upward from the lower brush to the higher, each upper brush, in this case, being the positive terminal of the circuit. The cut also shows that the brushes of the dynamo are advanced in the direction of the rotation, while the brushes of the motor are advanced backward in the opposite direction. The result of this variation in the arrangement of the brushes is, as is also indicated, the electromotive force in the dynamo, from which current is given forth, is in the same direction as the current, both moving from the lower to the upper brush, up either side of the armature. In the motor, however, where work is being done, and energy is leaving the circuit, the electromotive force is in a direction opposite to the current; the former moving from the lower to the upper brush, the latter from the

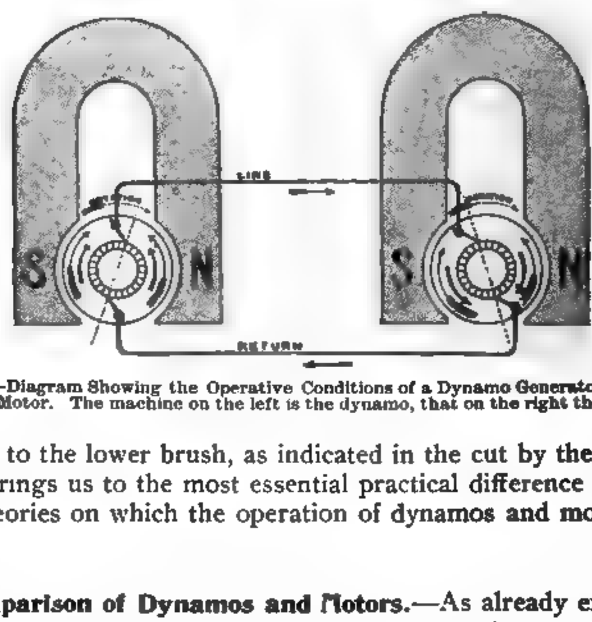



FIG. 288.—Diagram Showing the Operative Conditions of a Dynamo Generator and Electrical Motor. The machine on the left is the dynamo, that on the right the motor.

higher to the lower brush, as indicated in the cut by the arrows. This brings us to the most essential practical difference between the theories on which the operation of dynamos and motors depend.

**Comparison of Dynamos and Motors.**—As already explained in connection with the dynamo, the rotation of the armature cutting the lines of residual magnetism constantly tend to increase the electromotive force of the current conducted to the coils and the field magnets, with the result that the E. M. F. of the current generated is constantly augmented, as the induced magnetic lines increase in number of strength until the maximum is attained.

With the motor, however, the current fed to the circuit is imparted partly to the windings of the armature and partly to the windings of the pole magnets, with the result that, both assuming polarity, the magnetic action tends constantly to attract the opposite poles of the armature, thus imparting a rotative movement. Thus the magnetic drag, which in the dynamo acts in the direction opposing rotation, and is, in fact, the reaction against the driving force, is in the case of the motor the real driving force, which propels the revolving armature, representing the pulling influence which the magnetic field exerts upon the armature


FIG. 289.—Heavy truck of the Vehicle Equipment Co. Carrying capacity, 4 tons; speed, 6 miles per hour; travel radius on one charge of battery, 25 miles.

wires, through which the line current is flowing, and also upon the protruding metal portions of the armature core.

This operation is in accordance with the law relating to a current-carrying wire, situated in a magnetic field, in accordance with which it experiences a side-thrust, as it is called, which tends to move it forcibly in a direction parallel to itself, across the direction of the lines of magnetic force. This fact is well illustrated in Fig. 282, on page 397, in which the large arrow is represented as moving through the coil of wire, carrying current. The direction of the current in the wire is indicated by the small arrows, and the side-thrust, or magnetic push, by the large arrow.

**Action of the Field Magnets of a Motor.**—The second point to be considered in the practical operation of an electrical motor is that, while the magnetic action of the field tends to produce a rotation in the armature, the same rotation, necessitating that the armature windings cut through the magnetic lines of force, tends to the production of a counter electromotive force (C. E. M. F.), which, as previously mentioned, moves in a direction contrary to the direction of the current. As may be readily understood, the more rapidly the armature rotates, the greater will be this C. E. M. F., on account of the fact that a stronger field is necessary for the increase of speed, and, consequently,

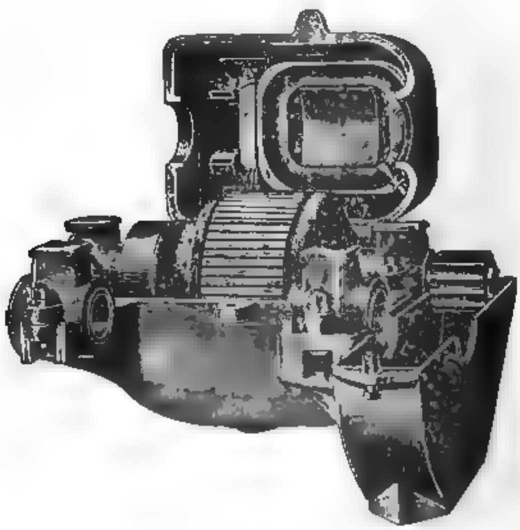


FIG. 290.—A Heavy Vehicle or Street-Car Motor, with single reduction, showing working parts in position.

that a greater number of magnetic lines are produced, which the armature must cut through.

Two facts, however, follow from this condition:

(1) As the armature revolves more rapidly, there is a diminished resistance to its motion, and on account of the increase of C. E. M. F. less energy is absorbed.

(2) When the motor is working under load, the armature necessarily revolves more slowly, with a consequent fall in the generation of C. E. M. F., and a greater absorption of energy.

**The Speed and Torque of a Motor.**—As may be understood from what has just been said, the increase of speed marks an increase of power in an electrical motor, just as in a steam or gasoline engine. There is, however, another consideration relating to the power of a motor, and that is the drag or rotative energy brought to bear upon the circumference of the pulley or spur attached to the end of the armature shaft. This electro-dynamic force, which tends to produce rotation of the shaft, is known as the torque, which is to say, the twisting power of the motor.

In estimating the efficient power of a motor, we have, therefore, to consider three elements:

(1) The power measured in pounds weight, which originally causes the rotation of the armature spindle, and which may be readily determined by experimenting with pulleys of various

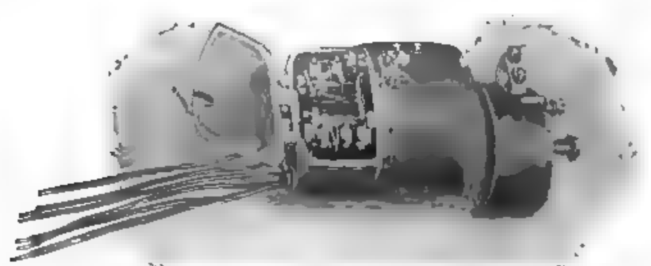


FIG. 291.—Type of General Electric Light Vehicle Motor, with case open, showing commutator and brush apparatus. The pinion end head is arranged for double reduction. Both end heads and gear housing are made of aluminum. Suspension by lugs to body. Capacity, 31½ amperes at 39 volts, 1,800 R. P. M. at full load.

sizes, showing the power to raise various weights, or by a form of Prony brake, somewhat of the same description as is used for determining the efficient power of a steam or gasoline engine, as has been already described.

(2) A second element entering into the determination of the efficient power of a motor is the diameter of the pulley.

(3) The number of revolutions per minute attained.

**Illustration of Torque.**—The operation of the torque of a motor may be illustrated by an accompanying diagram, in which, as shown, a rope wound about the axis of a pulley, *P*, and having a weight, *W*, attached to it, is able to cause the rotation of a

pulley through the force of gravity exerted on the weight, *W*. Now the efficiency may be determined by two considerations: (1) The number of pounds in the weight, *W*, and the diameter of the pulley, *P*. If, for example, the weight is fifty pounds, and the pulley is of the same diameter as the shaft around which the rope is wound, the weight, *W*, will exactly balance a weight equal to itself; if the pulley is twice the diameter of the shaft, the weight, *W*, will be balanced by a weight of twenty-five pounds, and so on indefinitely; the amount of weight necessary to balance weight, *W*, being always in inverse proportion to the difference in diameter between the shaft on which it is coiled and the pulley to which is attached the rope carrying the counter-weight. This is in accordance with the law of levers, that the power exerted on the long arm of a lever can raise a weight as much greater than itself, as the long arm is longer than the short arm, to which the

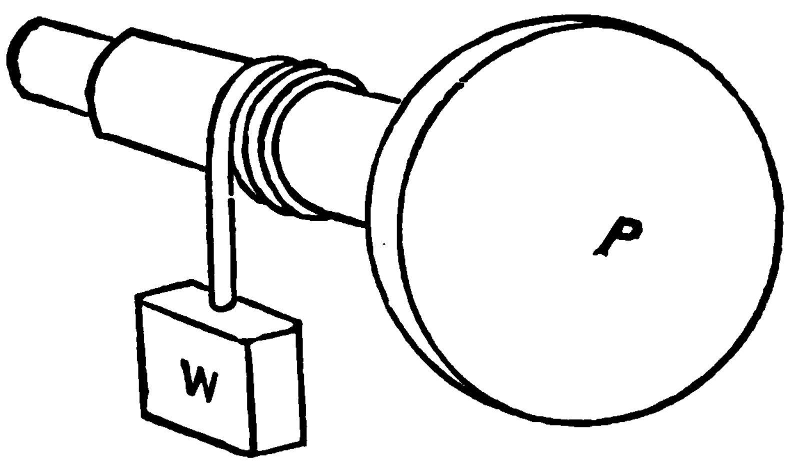



FIG. 292.—Diagram Illustrating the Theory of Torque.

latter weight is attached. Consequently, if the torque at the shaft of a motor armature is equivalent to 100 pounds for that diameter, it can exert a power of only fifty pounds with a pulley of twice the diameter of the spindle, and of only twenty-five pounds with a pulley of four times the diameter of the spindle.

This principle may be stated in another manner: that the pulley is capable of raising a weight which is in inverse ratio to the power exerted on the spindle of the armature, as the diam eter of the pulley is greater than that of the spindle, because the work required of it is to raise its weight through a vertical distance equal to its own circumference. If, then, a pulley of 1 foot circumference can raise a weight of 1 pound to a vertical distance of 1 foot, a pulley of 4 feet circumference can raise only $\frac{1}{4}$ of a pound through a vertical distance of 4 feet.

**Conditions of Motor Operation.**—The torque of a motor armature—being stated in terms of pounds weight constantly acting to rotate the spindle—furnishes the first element in all formulæ for calculating the power of such a machine. It is evident, however, that while it represents the element of *length*, as found in the circumferential measure of the armature, and of *mass* or *weight* as found in the total resistance to be overcome in achieving a given result, as found in the load against which the spindle must revolve, the element of time must be supplied, in order to give an idea of the dynamic stress constantly at work. In other words, if the torque necessary to move a given load be estimated as 100 foot-pounds, the power of the motor depends solely upon the question of whether that 100 pounds is exerted in the unit time or whether it is a cumulative effect of a smaller energy acting through several units of time. Thus, 100 foot-pounds in torque might accomplish the raising of a given weight on a pulley of given diameter in one second, but 10 foot-pounds would require 10 seconds to complete the revolution. Knowing, therefore, that a given effect, as for example, keeping a certain machine in constant operation, demands an expenditure of 3,600 joules, the whole question of power-rating for the motor depends on whether this energy represents one watt-hour or ten 0.1 watt-hours.

**Calculating the Power of a Motor.**—In estimating the power of a direct current electrical motor in terms of foot-pounds, the fundamental formula gives the product of the torque, as found by brake tests, by the angular velocity. The angular velocity, whose unit is one radian per second, or such a speed as shall enable a given point on the circumference of the spindle to traverse an arc equal to its radius—(this is described on the unit angle of $57° \ 17' \ 44.8'' +$)—is found by multiplying the number of revolutions per second by twice the ratio between the circumference and diameter of a circle, which is 3.141592, usually represented by the Greek letter $\pi$ (*p*). Thus:

Angular velocity$=6.283184\times$r. p. s.

Then, with a motor showing a torque of 50 foot-pounds and with 50 revolutions per second of armature, the power in foot-pounds would be found by this formula:

Power$=50\times6.283184\times50=15{,}707.96$ foot-pounds.

is the greatest per unit of length. The unit of reluctance is the oersted, which is equivalent to the amount of magnetic resistance offered by a cubic centimeter of vacuum. The reluctance of iron is represented by a fraction of this figure, although differing with the quality and variety, which determine the magnetic permeability of the core. It also increases as the magnetic flux reaches the point of retention of the core, which is estimated in gausses, or maxwells-per-cubic-centimeter, in order to indicate the degree of magnetic density. In this respect again a magnetic circuit is analogous to an electrical circuit, in which the effect of increasing the pressure beyond a certain safe point for a given size of wire—thus, of course, increasing the electrical current—is that the wire becomes overheated, the resistance is raised and dangerous consequences are liable to ensue. Thus, with a magnetic circuit also, the field-intensity increases with the rise of current in the coil, until the point of saturation is reached; after which the increase is on a much lower ratio.

In estimating the resistance of an electrical conductor, the operation usually followed is to find its diameter in terms of mils, or thousandths of an inch, and divide the square of this figure, or its area in circular mils, into the product of length by the unit resistance. The unit resistance is the number of ohms per mil-foot at zero centigrade, or the resistance of a wire 1-1,000th inch diameter and one foot in length. For copper wire this is 9.59 ohms. Hence, in order to find the resistance of 1,000 feet of No. 36 B. & S. (diameter 5 mils, area 25 circular mils) at zero centigrade we proceed as follows:

$$\text{Resistance} = \frac{1{,}000 \times 9.59}{25} = \frac{9{,}590}{25} = 383.6 \text{ ohms.}$$

In the same manner the usual formula for reluctance gives the quotient between the length of the solenoid in centimeters by the product of the area and the magnetic permeability, which latter quantity is the reciprocal of the reluctance. Since these quantities must be determined largely by experiment, or by reference to tables of magnetic conditions, it is more convenient to determine the reluctance from the flux found in terms of maxwells. However, in estimating for dynamos and motors, the reluctance of the air-gap, or clearance space between the armature and the poles, is an important factor.

In calculating the flux in the core of a magnet all formulæ whatsoever are based upon considerations that can be determined solely by experiment, among which are the number of ampere turns per unit of length, the magnetic induction, field intensity and permeability. The fundamental formula for determining the flux gives:

$$\varphi = \frac{4\pi NI}{L} \times A,$$

which is to say, the ratio between the quotient of 12.566368 and the number of ampere-turns by the length of the solenoid, multiplied by the cross-sectional area of the core. This formula, therefore, gives the product of the magnetizing force by the cross-section of the magnet. The magnetizing force is theoretically equivalent to the length of the pole, which may be determined as the quotient between the force exerted by the pole and the unit of polar strength. The unit of polar strength or field intensity is such a repelling force as is sufficient to act upon another unit pole of like polarity with the strength of one dyne, or fundamental C. G. S. unit. The pole-strength of a stronger, or of a weaker, magnet, is, therefore, equal to the quotient between its determined energy and the unit. The flux of a magnet is consequently to be found as the product of the pole-strength in dynes by the cross-sectional area, although in designing and accurately calculating motors and other types of magnetic machinery the formula previously given, including the number of ampere-turns, is necessary.

**Power in Terms of Electrical and Magnetic Units.**—In calculating the power efficiency of an electrical motor the effective flux may be experimentally determined in terms of watts ($10^7$ C. G. S.), as the force with which the field poles exert a rotative pull upon the armature. In this calculation the number of watts realized in work represents a given percentage of the watts delivered at the motor terminals, the difference between the two figures having been absorbed in internal resistance during operation. According to standard formulæ:

$$\text{Input watts} = \text{E. M. F.} \frac{\text{E. M. F.—C. E. M. F.}}{\text{Internal Resistance.}}$$

$$\text{Efficient watts} = \text{C. E. M. F.} \frac{\text{E. M. F.} - \text{C. E. M. F.}}{\text{Internal Resistance.}}$$

By solving these equations we find that the following ratios **hold**:

$$\frac{\text{Input watts}}{\text{Efficient watts}} = \frac{\text{E. M. F.}}{\text{C. E. M. F.}}$$

However, the efficiency of a motor in terms of watts-output depends upon the number of revolutions per second, since the stronger the flux the greater the speed. Thus, the efficiency in watts is determined by the following formula:

$$\text{Efficient watts} = 2\ (3.141592) \times \text{r. p. s.} \times \text{T}\frac{746}{550}$$

in which is found the product of twice the ratio between the circumference and diameter of a circle by the revolutions per second, by the product of the torque (T) in foot-pounds at one foot radius of the armature and the ratio of watts to horse-power, reducing it to terms of $10^7$ C. G. S. units.

While exact calculations for the design of a motor to give a certain power-effect involve the use of more complicated fomulæ, other authorities give readier average methods for determining the quantities involved in an active motor. Thus the reluctance per cubic unit of air clearance and iron core may be readily calculated for the M. M. F. generated by a solenoid of a given number of ampere-turns. To estimate the useful flux in an armature core several authorities give formulæ based upon the average magnetic density employed in motor armatures. According to average accepted figures the point of magnetic saturation of the core is about 16 kilogausses, and the average efficient flux about 10 kilogausses, or 10 maxwells-per-square-centimeter of cross-sectional area. To reduce to square inches, we multiply by 6.45, finding that the figure for magnetic saturation is about 103,200 gausses, and for average effective flux about 64,500. The average effective flux may be estimated, therefore, as the product of the cross-sectional area of the armature in square inches by the 64,500.

Knowing, then, the number of turns of wire, or complete convolutions on the motor armature; the safe current strength in amperes passing through the winding between the brushes, and

the approximate useful flux, the torque of the motor in foot-pounds my be found by the following formula:

$$T = \frac{N \times I \times \varphi}{85{,}155{,}000} = \text{foot-pounds.}$$

**Horse-Power of an Electric Motor.**—In testing the horse-power capacity of a given motor at normal voltage, required factors of torque, speed and radius may be readily found—the first by brake test, the second by tachometer or speedcounter, and the third by simple rule measurement. These quantities having been determined, the horse-power may be found by the following formula:

$\text{H. P.} = \frac{T \times R \times S \times 2\pi}{33{,}000}$, in which $T$ is the torque in foot-pounds; $R$, the radius of the armature; $S$, the speed in ***revolutions per minute;*** $2\pi$ the constant 6.283. The denominator represents the number of foot-pounds per minute making one horse-power.

# CHAPTER THIRTY-FOUR.

## MOTORS FOR ELECTRIC VEHICLES.

**Electrical Carriage Motors.**—In several very essential particulars the motors used on electrical automobiles are masterpieces of the designer's art. The conditions under which they are used demand that they yield a high percentage of efficiency, in spite of their low power-rating; that they be capable of operating under several different pressures, and at as many different speeds; that they be independent of any such safety devices as fuse wires and cut-outs, and that they give good results at all loads.

Stationary motors are designed to operate at certain maximum figures for both load and pressure, and are provided with automatic protectors, which open the circuit so soon as the limit of safety in either particular is reached. The speed and power output may be regulated by adjustable resistances, so as to accommodate any requirement of load, and, since such variations are within a moderately limited range—always between points definitely predetermined—it is possible to arrange the windings to give the highest possible efficiency.

An automobile motor, on the other hand, must frequently operate at several hundred per cent. over load, as when propelling the vehicle up a steep incline or over a heavy road. Moreover, under such conditions, it is impossible that fuse wires and cut-outs be used, since the point of overload is the very time that such full power is required. The unusual strain put on a motor on such occasions is not the only test of endurance and capacity, since it is frequently handled by a driver in such manner as to tax it severely; in starting from a standstill to ascend a heavy grade, to take an unusually rough road, or to begin travel with a heavy burden in freight or passengers, at the highest voltage.

In another respect an automobile motor must possess exceptional qualities—it must combine strength and lightness, so as to ensure good operation amid all the jolting and vibration of travel, with the fewest possible repairs. Its working parts, particularly the commutator and brushes, must be readily accessible, so as to

be rapidly inspected and repaired, when necessary, and all electrical connections must be as firm and permanent as possible. In order to prevent crystallizing, short-circuiting and other injuries to the conductors flexible cables are always used between motors and batteries. The requirements as to the strength and firmness of construction appear particularly strenuous, when we consider that the vehicle must most frequently be driven by a person unskilled in the theory, management and repair of electrical machinery.

Among the first mechanical requirements in a vehicle motor are those that promote easy operation. Thus, all rotating parts move on ball-bearings, while the end of perfect lubrication is secured by wick cups or adjustable compression oilers. The entire mechanism is carefully enclosed in a tight case, in order to prevent abrasion from dust, grit, etc.

Since, as already stated, a vehicle motor is liable to be called on for sudden overloads at almost any time, its working parts must be carefully designed and adjusted to operate with the smallest possible percentage of such mishaps as are peculiar to electrical apparatus. Thus, it is necessary that the *insulation* used on all parts should be of a material capable of withstanding the high temperatures generated by work, without danger of burning-out. Suitable materials are found in asbestos and mica, both of which are largely used in up-to-date motor construction. For the same reason, good *ventilation* should be secured by even more thorough facilities than are used on any other variety of electrical machine. The *commutator* is another part requiring careful attention. It should not be so small as to spark and splutter on overloads, which is to say, its bars or segments should not be so numerous, in proportion to its size, as to involve sparking and overlapping with brushes of sufficient diameter to carry the required current.

This brings us to a consideration of the brushes, which must be of such material as to permit of firm adjustment, without grooving the commutator, and without offering too high a resistance to the current. In order to secure the ends of firm adjustment, without sparking or grooving, brushes composed of carbon, or some carbon combination are used on many automobile motors. Carbon is particularly suitable for this purpose, since it admits of permanent adjustment, thus preventing the

many motor mishaps that come from poor brush arrangements. On the other hand, its resistance, according to many authorities, renders it unsuitable to permit of good work at the low voltages used on electric road vehicles. For this reason copper gauze brushes still have their advocates, who claim superiority, from the facts that lower resistance may be thus attained; also that, when properly constructed, they may be sufficiently well lubricated. Such brushes, when disposed radically on the surface of the commutator, can be firmly adjusted and offer sufficient resistance to give good commutation. In order, however, to avoid

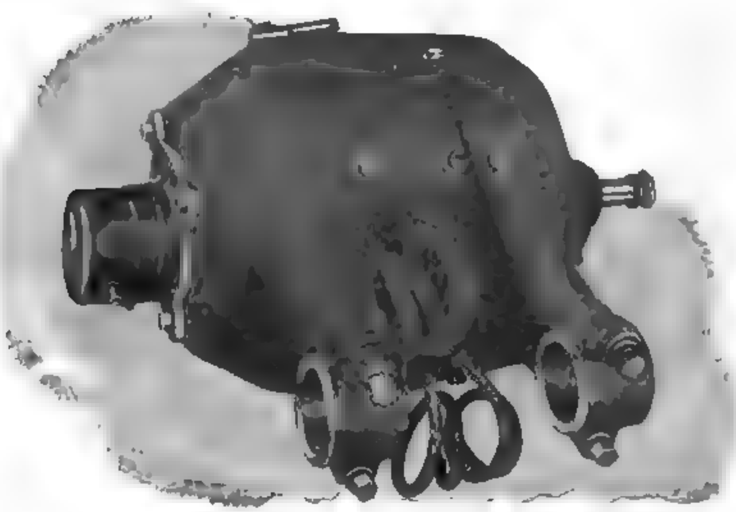


FIG. 293.—General Electric Motor, Designed for Heavy Vehicle Use, with single or double reduction. Capacity, 30 amperes at 85 volts; 800 R. P. M. at full load.

the disadvantages of both carbon and copper, and, to secure the good results to be found in either case, the practice of using a combination carbon and copper gauze brush is increasing among motor manufacturers and carriage builders. This latter may be said to be the really typical construction at the present time.

**Summary of Vehicle Motor Requirements.**—The General Electric Co., whose motors are widely used on American electric carriages, summarizes the requirements as follows:

"To attain the maximum possibilities in thoroughly efficient and reliable apparatus, the manufacturer must consider that combination which will give proper structural strength, added to the highest electrical efficiency. A properly designed motor for use in connection with storage batteries must possess a well-sustained efficiency curve at overloads, together with fine speed and torque characteristics. The amount of iron and copper used must not be stinted, for although generous proportions in this respect may add somewhat to the weight of the motor, this increase is more than counterbalanced by the resultant improvement in the torque, speed and efficiency characteristics obtained, besides decreasing the heating effect. It is obviously of small importance if a slight increment be added to the weight, if by so doing a motor is able to respond at once to extreme overloads without 'lying down' or unduly taxing the batteries, which at best are especially susceptible to injury by over-discharge. Again it is important that the speed and torque curves bear a proper relation to each other through all the range of the motor's load. This relation is a direct function of the efficiency of the machine and is only to be obtained by a judicious liberality in the use of high grade material.

"The mechanical characteristics of the General Electric Co.'s automobile motors have received very careful attention. The designs have been carried out on the sturdy lines of the street railway motor, particular care having been exercised in providing generous bearings, rigid shafts, simple and durable brush fittings and commutator segments of such width and depth as to insure good commutation at all loads and long life of the parts. The frames of all General Electric automobile motors are made of cast steel, and the poles of laminated iron. Field and armature coils are machine-wound and thoroughly taped and waterproofed. The armature shafts are tapered and provided with a nut for securing the pinion."

**Power Efficiency of Vehicle Motors.**—The power range of the average automobile motor is remarkable. Thus, a motor rotated at three horse-power is usually wound to develop at least nine horse-power, or to take a 200 per cent. overload at the highest voltage. Few reliable authorities claim a higher capacity than this. However, as stated by one manufacturer, a motor for a 2,000-pound, two-passenger runabout, rated at 2½ horse-power, con-

sumes 6,800 watts in ascending an 11 per cent. grade at 7 miles per hour, although no more than 360 watts are required to propel the carriage on an even asphalt roadway at 8½ miles per hour. These figures represent an effective power-range of between ½ horse-power and over 9 horse-power. There seems to be some uncertainty as to the precise power-rating of carriage motors, but, as matter of fact, they are wound to develop the highest constant power-output at the highest voltage (80 volts) used, with a high overload capacity for short spurts, as in hill-climbing, etc.

**Operation of a Series Motor.**—The motors used on electric carriages are generally series-wound, that type having been

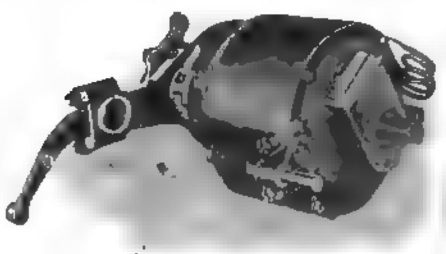


FIG. 294.

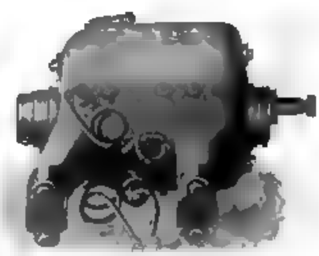


FIG. 295.

FIG. 294.—General Electric Siemens-Halske Type of Vehicle Motor. Four-pole, cylindrical, laminated fields. Capacity, 16 amperes at 80 volts; 1,000 R. P. M. under full load.

FIG. 295.—General Electric Motor for Medium-weight Vehicles. Capacity, 16 amperes at 85 volts, 850 R. P. M. at full load.

found very well adapted to most ordinary requirements, and from many points of view the most efficient in operation. It also possesses the valuable characteristics of automatically adjusting the consumption of power, as it were, to the load. Thus, at a light load it will take small current, while, as the resisting torque on the machine increases, power sufficient for demands is constantly absorbed, thus enabling the motor to take extreme overloads with high efficiency. It is wasteful, however, at very light loads, as in descending hills. Since, in a series motor, the total internal resistance is equal to the sum of the armature resistance and the field resistance, it follows that the current is the same under an

even load at any speed, and that the torque is in nearly direct proportion to the current. At a light load, with a small current, the rotative speed of the armature is comparatively great, and, owing to the generation of a high C. E. M. F., cuts down the current fed from the mains, in proportion to the difference between the impressed voltage and the internally generated voltage. Two things follow, therefore; that the efficiency is reduced at high speeds, and that it is reduced at light loads. With a heavy load, reducing the speed, the efficiency is correspondingly increased. Consequently, the most conspicuous problem before the practical motor-designer is how to produce a motor that will give a power-output proportionate to the weight of the motor, and, at the same time, rotate its armature at a comparatively low speed. This principle is amply demonstrated in the familiar fact that a motor, developing a low speed at a given power, is capable of being wound a higher voltage and can take large overloads, while one developing an unusually high speed per power unit it capable of small efficiency at any load. It may thus be seen that an increase of load, or resisting torque, acting to reduce the speed of armature rotation, will cut down the C. E. M. F., and, rendering a greater pressure available, will permit a greater current to flow in the windings, with the result of creating a greater flux, and, consequently, also, a greater power effect. This condition is explained by a simple application of Ohm's law. Thus, if the electrical resistance of a given armature winding be 1 ohm and the pressure between the mains is 20 volts, the current strength would normally be 20 amperes. Supposing, now, that the C. E. M. F. generated when running free be equal to 12 volts, the effective pressure will be represented by the difference between 20 and 12, or 8 volts, thus reducing the current to 8 amperes. As a general statement of the principle involved, it may be asserted that an increase in the resistance of the armature winding—by using a large number of fine wire turns—involves a large generation of C. E. M. F. for given rates of speed, and, consequently, a large drop in both pressure and speed under load. If, on the other hand, the armature resistance be small—the winding consisting of comparatively few turns of coarse wire—a given C. E. M. F. would involve a correspondingly higher speed for its generation, while a far larger proportionate current and torque would result with given decrease in the speed of rotation.

**Speed and Output of Power.**—It seems evident that increase in pressure, involving high speeds at small loads, entails a corresponding loss of efficiency—judging this as the difference between the input and output in watts or kilowatts—thus enabling us to assert that the best efficiency of the motor and the greatest economy of current are both attained by using low pressure at light loads, and raising the pressure only with the increase of load. Such a rule is limited, of course, by considerations of the motor's construction, and the range of current strength to be obtained in its windings with definite variations of pressure. If, therefore, the armature of a given motor is wound with 1,000

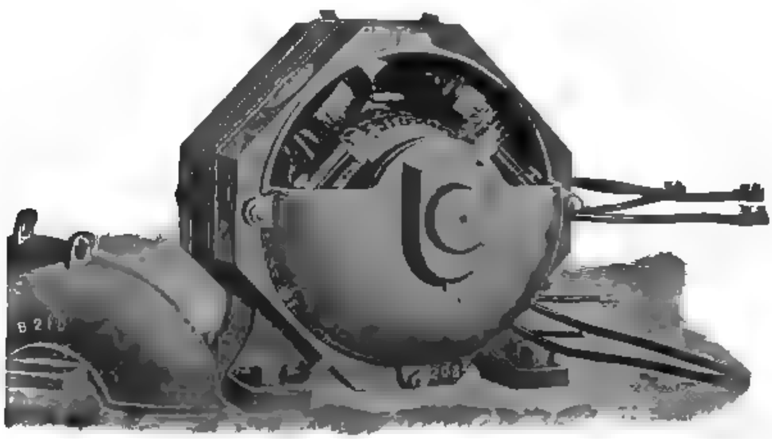


FIG. 296.—The "Lundell" Octagon Four-pole Motor, with case open, showing parts. Laminated field magnets and armature core. For vehicle use ranging between 2.5 and 15 horse power, wound for 80 volts. At this pressure the 2.5 horse power takes 28.5 amperes; the 5 horse power, 55 amperes, the 10 horse power, 110 ampers, the 15 horse power, 160 amperes.

complete convolutions of wire, representing, say, a resistance of 5 ohms, it will carry a current of 16 amperes at 80 volts, of 8 amperes at 40 volts, and of 4 amperes at 20 volts, giving for the three variations of pressure, 16,000, 8,000 and 4,000 ampere turns;

**Motor Development in America.**—In desiging or estimating the efficiency of an electric motor it must be always borne in mind that the lower the power rating the greater the speed of armature rotation. Thus, while a good ½ horse-power motor has a normal speed of 1,300 revolutions per minute at full load,

or 2,600 revolutions per output of horse power. a 1 horse-power motor has a normal speed of only 1,000 revolutions per minute, under load a 5 horse-power motor, but 900 revolutions, or 180 revolutions per horse-power output; higher powered motors have even lower speeds. As can be readily understood, therefore, the lower the horse-power rating, and the higher the speed, the lower the efficiency. Thus, with the speed of rotation above mentioned, the average 1 horse-power motor has an efficiency of about 72 per cent.; a 6 horse-power motor, of about 81 per cent., and no motor

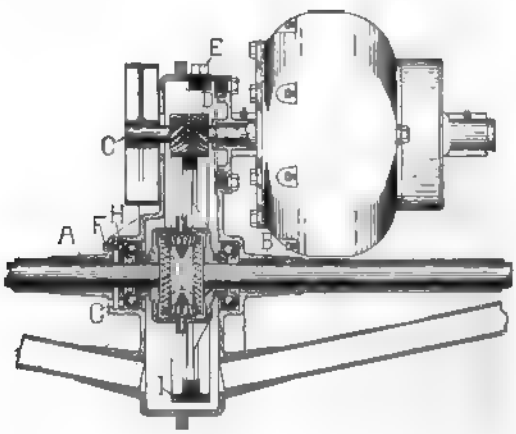



FIG. 297.—Plan Diagram of Single Motor Attached to Rear Axle Through "Herring-bone" Single Reducing Gears. A is the left-hand section of the divided rear axle, B, the right-hand section of the rear axle; C, the brake drum; D, the spiral pinion on the motor shaft driving the worm gear, I, on the differential; E, plug for greasing gears; F, set screw for locking ball race; G, slot for wrench to adjust threaded ring, H, against ball bearings.

of much over 90 per cent. In comparison with these figures, we may quote the published statements of several manufacturers of carriage motors, as showing the high state of perfection of motor-design at the present time in America. One manufacturer, the Elwell-Parker Co., producing three sizes of carriage motor, rated respectively, at ¾, 1½ and 2½ horse-power, claims a speed of 1,200 revolutions per minute, and a 79 per cent. efficiency, for the first; a speed of 1,050 revolutions, and 80 per cent. efficiency for the second; and 850 revolutions and 82.5 per cent. efficiency for the third. These machines weigh 83, 115 and 155 pounds, and measure complete with cases, respectively, 9⅝x12 7/10",

10 9/10x14½", 11½x17 6/16". The first figures in each instance are for diameters, the second, for length of case, not measuring the spindle at either end.

**Shunt and Compound Motors.**—With a view to increasing the efficiency of automobile motors, several designers have proposed the use of shunt and compound windings, whose advantages in several particulars have been made apparent in other branches of electrical activity.

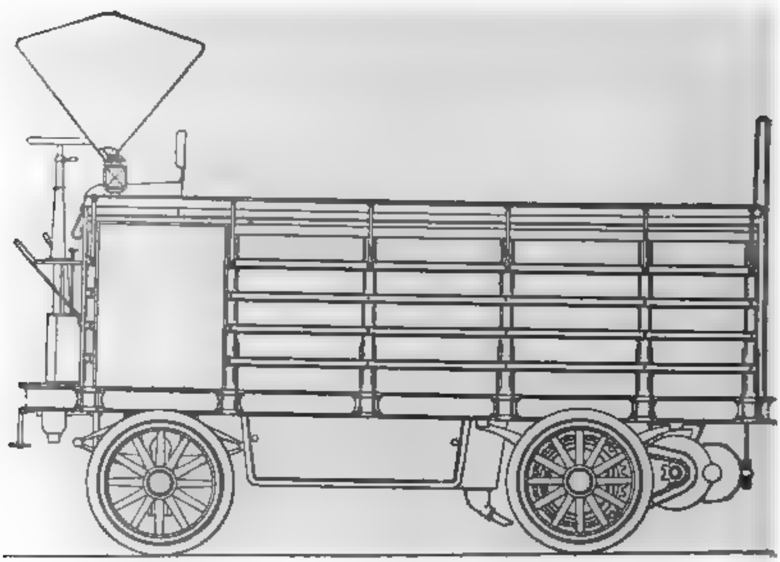


FIG. 296.—Chain and Sprocket Double Reduction for Heavy Trucks. As here shown, the motor is hung above the springs, missing the jars of travel.

Shunt-wound motors, in which the field coils, instead of being in series with the armature, are on a shunt between the lead terminals, are very largely used on constant-potential circuits, on account of their ability to regulate the speed, maintaining it at a virtually uniform rate, in spite of the increase in load up to a certain point. With differential-wound compound motors the same effect of speed regulation may be attained, on a constant-

potential circuit, by the interaction of currents in a low-resistance winding in series with the armature and a high-resistance coil in shunt. The former coil as a demagnetizer, causing the motor to speed up under increased load, by weakening the field, which furnishes an offset to the tendency to slow down, under such conditions, always varying the magnetic strength inversely to the load. Of course, at very excessive overloads the danger is that the current in the series winding will completely neutralize that in the shunt, with the result of checking armature rotation, and often involving even greater disadvantages.

Regarding the use of shunt-wound motors in electric carriages, a well-known automobile authority writes as follows: "The use of shunt motors on street cars driven by storage batteries was

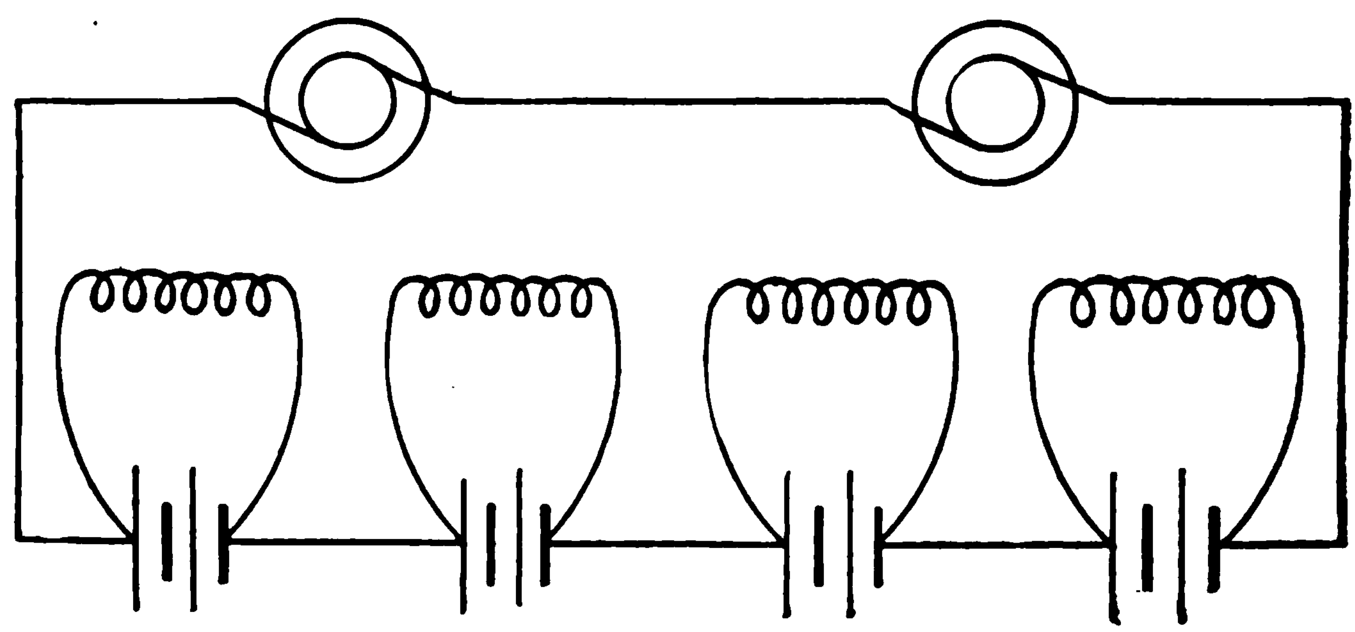


FIG. 299.—Diagram of Circuit Arrangements with Shunt Motors, as explained in text.

early claimed as a great advantage. but most automobile motors are series-wound. This cannot continue, for the advantages of shunt motors are too manifest. What better method for braking is there than to drop the controller off a notch or two, and, with the motors acting as dynamos, turn the surplus energy back into the battery? The ammeter provided on most electrically-driven vehicles is a perfect guide in doing this. The instrument should be differential, and, as the needle comes back to zero, notch by notch may be turned off. In hill-climbing, one third and even more of the extra energy consumed can be recovered by coasting down the other side with the controller set a notch or two below the coasting speed. These well-known possibilities of shunt

motors could not be fully attained on street cars, but with automobiles the problem is very easy.

"Full field strength should be used at all times. The first act of the controller should be to make the field connections, and this condition need not interfere with the commutation of the cells. The field coils may be divided into as many sections as batteries, and each battery given a section. This arrangement will not interfere with the batteries being switched in any series or multiple combination that may be desired. In the previous figure two motors are shown in diagram, each of which has two field coils. The battery is divided into four sections, a very common arrangement, and each section excites a field coil."

Such an arrangement as is here suggested, combined with a series field coil, has evidently been put into operation by one or two manufacturers. Of course, with uniformly-wound shunt and series coil, both fields are greatly excited at high load, and, the magneto-motive force of both acting in the same direction, the energizing flux would be somewhat increased, with consequent reduction of armature rotation, in developing the required C. E. M. F. Proper adjustment can largely neutralize the drop in speed that is liable to follow the drop of pressure in the armature resistance, thus enabling the maintenance of nearly constant speed under nearly all loads.

## CHAPTER THIRTY-FIVE.

### PRACTICAL POINTS ON MOTOR TROUBLES.

**Electric Motor Troubles.**—The following digest of common motor troubles is given by Mr. George T. Hauchett in *The Automobile,* and is re-printed by permission:

"While it is not necessary to be an electrician to operate an electrically driven vehicle, it is of great advantage to know what to do when certain troubles occur.

"Let us consider first a single motor equipment provided with a battery which is connected in different ways for the various speeds. Suppose an attempt is made to start, and the vehicle does not respond and the ammeter shows no indication. This almost invariably means open circuit; that is to say, the path for the electricity from the batteries to the motors is not closed. We may find open circuits at any of the following points:

"A. The battery contacts. They may be and often are so badly corroded as to prevent the necessary metal-to-metal contact.

"B. The controller. A connection may be loose or the fingers may not make contact.

"C. The running plug may sometimes be out or not making proper contact.

"D. The motor brushes. May have dropped out or the tension may be so weak that they do not make contact.

"E. The emergency switch may be open.

"Leave the controller till the last. It is but a moment to inspect the other joints and to discover the trouble in them after an hour's fussing with the controller is clearly a waste of time.

"If the carriage operates at any of the speeds and fails to operate on the others, the ammeter needle falling to zero, the trouble is almost certainly in the controller. The contact fingers that are brought in play at the inoperative speeds should be inspected. Often a screw adjustment or a rub with a piece of emery cloth will correct the difficulty.

"If the motor tries to start, but the current is not sufficient, as shown by the ammeter, poor contact or weak battery may be suspected. Discharged battery will be betrayed by a low voltmeter

indication, but if the voltmeter registers the normal amount, poor contact should be sought. Any contacts which are part of the electric circuit, such as binding posts, brushes, switch jaws or controller fingers must be bright metal-to-metal contacts. If they are dirty or corroded the contact may be so bad that the flow of current is seriously reduced or interrupted altogether.

"**Improper Connections.**—Sometimes the absence of ampere indication and no motion of the vehicle points to a very serious trouble, namely, the improper connection of the batteries. This will be shown by heavy sparks at the controller; in fact, heavy sparks at the controller, absence of ammeter indications and refusal of the vehicle to move, could only be caused by one other difficulty than this, which will be discussed further on.

"When the battery is not properly connected, the motion of the controller causes the sections of battery to exchange current between themselves at a ruinous rate. The terminals of the cells and those to which they should be connected ought to be plainly marked, or, better still, so constructed that it is impossible to go wrong. If the trouble just cited is the fact, one or more sets of terminals of the cells will be found to be connected to the wrong wires.

"If the vehicle fails to move and the flow of current as indicated by the ammeter is enormous, shut off the power at once. Serious damage may ensue if this is not done. Then look to see if:

"A. The brakes are on.

"B. The vehicle is stalled or blocked.

"C. The gears are free and there is no obstacle between the teeth.

"If the motor makes a noticeable attempt to move the trouble is probably something of this mechanical nature.

"**Short Circuits.**—If, however, large current is indicated and the motor remains absolutely inert, the trouble is electrical, and the inference is that the current does not go through the motor at all. Lift one of the motor brushes and try the vehicle again. If the large current is still indicated, the inference becomes a certainty. This trouble is known as short circuit, that is to say, a spurious path for the current which deflects it out of the motor.

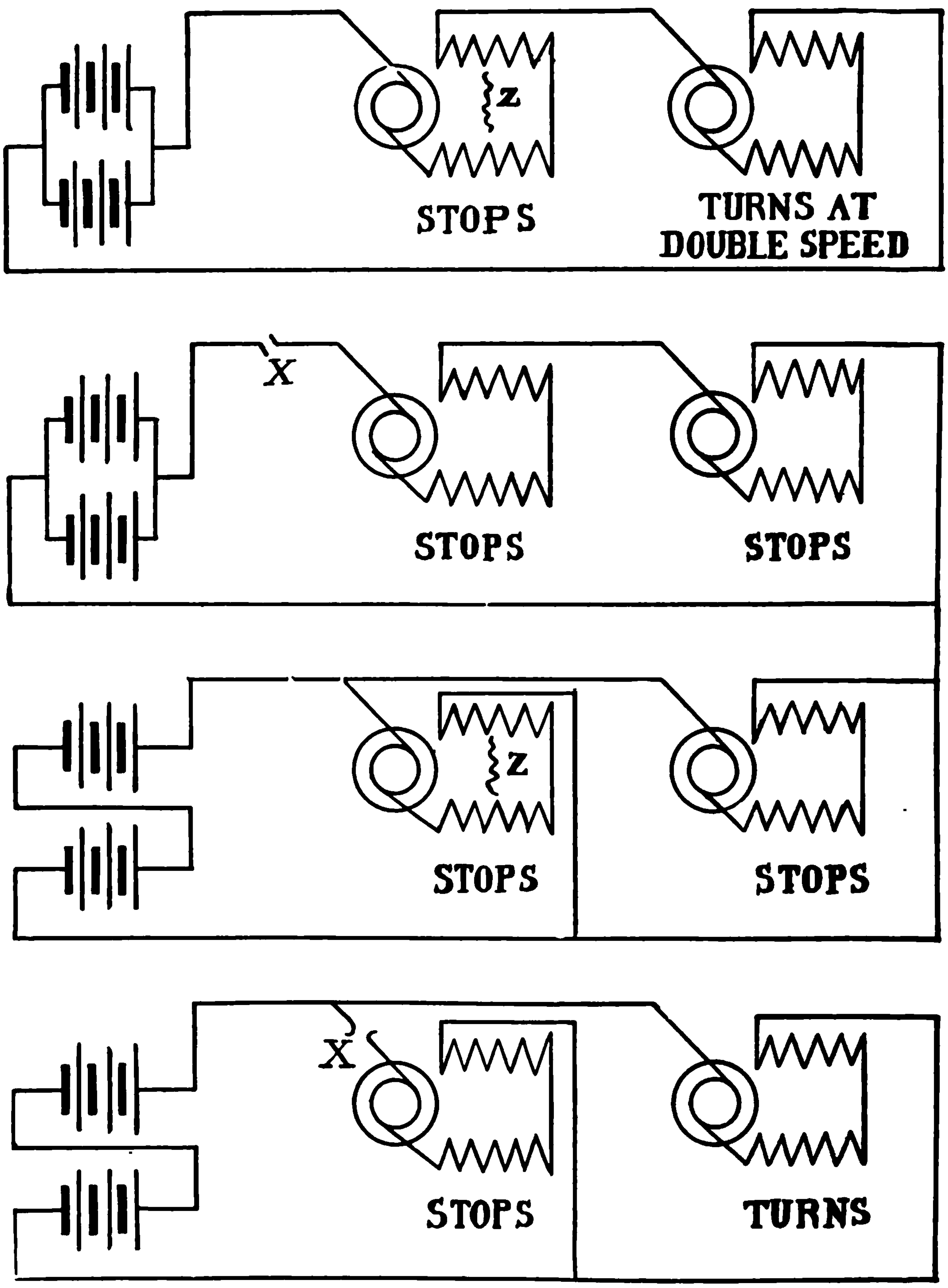



FIG. 300.—Diagram of Common Motor Troubles, as described in the text.

In the controller may be sought:

"A. Foreign pieces of metal making contact between portions of the electrical circuit.

"B. Loose fingers which may make contact with wrong parts of the controller or with each other.

"C. Dirt between the fingers or contacts.

"D. Breaks in the insulation permitting the wires to make contact with adjacent metal or with each other.

"If the controller appears to be all right, look in the motor for:

"A. Broken insulation, allowing the bare wires to touch the frame or each other.

"B. Dirt between contacts or between live metal and the motor frame.

"C. Foreign materials bridging contacts.

"In such a case it is sometimes of assistance to turn on the current for an instant. The defective place may betray its locality by a smoke or spark.

"If, when the brush is lifted, and the vehicle tried, the excessive current indication disappears, there are but two electrical troubles that are possible:

"A. The magnet coils of the motor may be short circuited.

"B. The ammeter may not be reading correctly.

"The latter trouble is least likely; the former should be sought first.

"A series motor with a short circuited magnet coil will call for a large current but will do nothing with it. Therefore, examine the magnet coil terminals for troubles of this nature.

"A short circuit may exist even if the ammeter does not indicate it. In such a case it is usually found in the controller, which sparks heavily when operated, although the vehicle does not move. This combination of phenomena also indicates improper connection of the batteries, as has been previously explained.

"An excessive call for current is accompanied with a drop in the voltmeter indication.

**"Two-Motor Troubles.**—With a two-motor equipment the difficulties that may arise differ but little. A few which are peculiar to this type may be mentioned. Such motors are sometimes run in two ways. The first notch connects the motors in

series, while the higher speed notches connect the motors in parallel. If one of the motors open-circuits on a series notch, the vehicle stops, for the entire motive circuit is broken. If it open-circuits on a parallel notch, that motor stops and the other, with its circuit to the batteries intact, continues to run and may cause the vehicle to make some abrupt and unexpected turns. If either of the motors gets short-circuited, the exact converse takes place. If the accident occurs on a series notch the unimpaired motor continues to run, and, it may be added, at nearly double its previous speed. If it occurs on a parallel notch a short circuit on one motor constitutes a short circuit on the other also, and if the short circuit is sufficiently severe both motors will stop, even though an enormous current may be drawn from the batteries."

## CHAPTER THIRTY-SIX.

### METHODS OF CIRCUIT-CHANGING IN ELECTRICAL MOTOR VEHICLES, AND THEIR OPERATION.

**Varying the Speed and Power Output of a Motor.**—The methods employed to vary the speed and power output of an electric vehicle motor consist briefly in such variation of the electric circuits as will modify the pressure of the batteries on the one hand and the operative efficiency of the motors on the other. This is a very simple matter and may be expressed in a few words. As is well known, there are two general methods of connecting up both electric batteries of any description and electric motors. They are the series-wiring and the multiple-wiring, or parallel-wiring. In series-wiring, various cells of a galvanic battery, or the several units of a battery of dynamos, are connected in line. At one terminal of each is the negative pole, at the other the positive—each unit in combination having its negative pole connected to the positive pole of the one next following. In the parallel method of wiring the various units are each separately connected at their positive and negative poles to two lead wires, one of which is the positive pole of the battery, the other the negative.

**Effects Obtained by Varying the Circuits.**—Electric motors, lights and other electrically effected devices are similarly connected in circuits, either in series or parallel. Now, in the matter of circuit arrangements on this plan, one general principle may be laid down, which is that a connection of a number of electrical generators in series involves an increase in the power pressure of the battery, which is equal to the sum of the individual voltages. Connecting a number of generating units in parallel or multiple has the effect of producing a pressure only equal to the voltage of one of the units. Thus, if four generators of 10 volts each be connected in series, the pressure is equal to 40 volts. If, however, they be connected in parallel or multiple, the pressure is equivalent to but 10 volts, the effect in the latter case being the same as if but one unit were in circuit, so far as

the voltage is concerned. On the other hand, where four motors are connected in series the efficient pressure of the circuit is reduced to very nearly $\frac{1}{4}$ for each motor, the C. E. M. F., generated by their operation, serving to cut down the average of efficiency; but when four motors are connected in parallel, which is to say, bridged between the limbs of the circuit, the greatest available pressure of the battery is able to act upon each one of them.

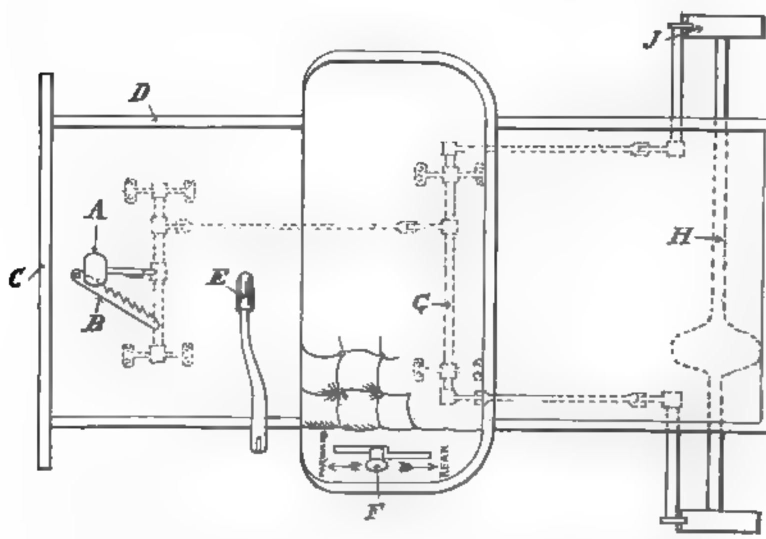



FIG. 301.—Diagram of the Controlling Apparatus of a Columbia Light Electric Vehicle. A, brake pedal; B, ratchet retaining pedal in place, operated by left foot; C, dash board; D, body sill; E, steering handle; F, controller handle; G, rocker shaft for setting hub brakes; J, brake band on wheel hub; H, rear axle.

**Arrangement of the Batteries and Motor Parts.**—In an electric vehicle the storage batteries are arranged so as to form a number of units, the circuit wiring being so arranged that by the use of a form of switch known as a controller the connections may be varied from series to multiple, or the reverse, as desired. The same arrangement for varying the circuit connections is used for the field windings, and, with some manufacturers, for the brush connections also. In the accompanying first diagram of the connections of an electric vehicle this fact is indicated. The dotted lines on each figure indicate the cir-

cuits that are cut out, or open, and the full lines those that are active, or closed. In the figure showing the first speed, we have the two units of the battery, *B*, connected in multiple, which means that the voltage is reduced to the lowest point. The wire, *C*, connected to the bridge between the positive poles of the battery, leads the current to the field windings, *H* and *J*, which, in this figure, are connected in series-multiple, which

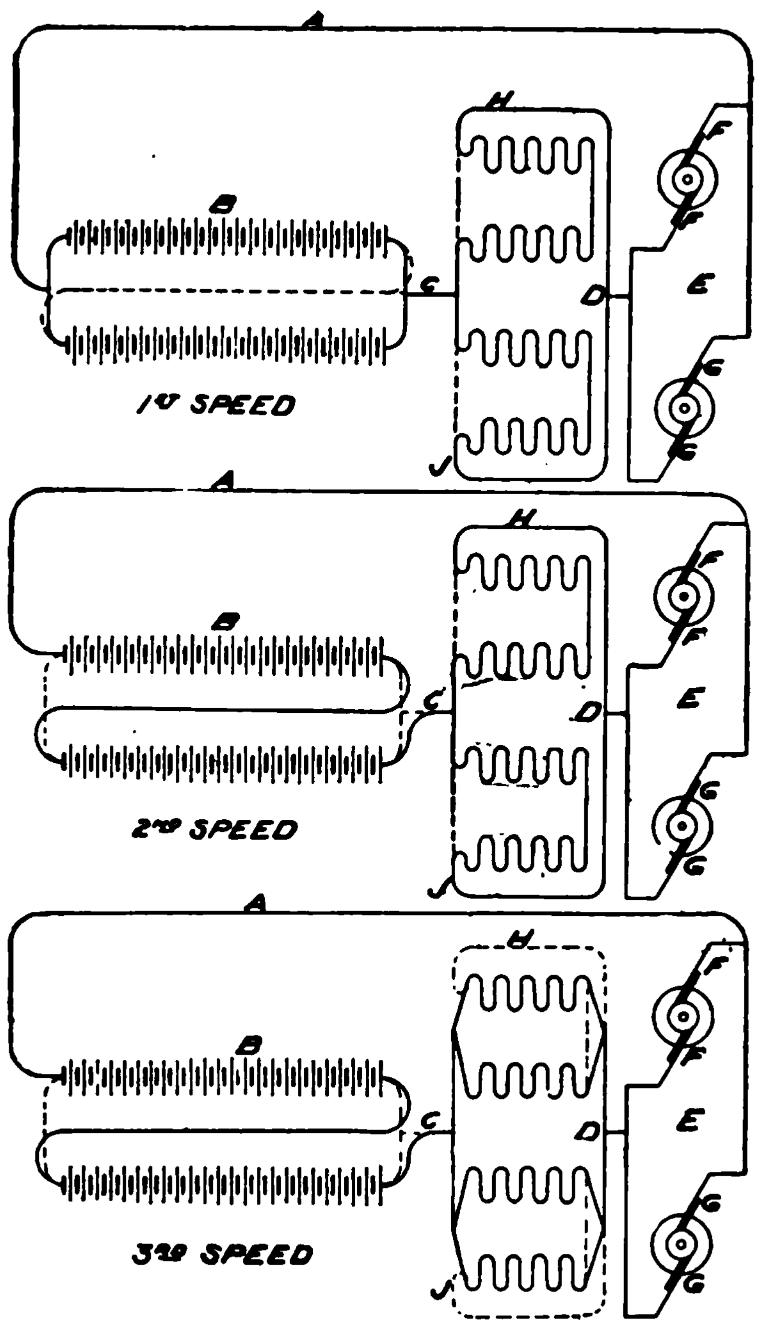



FIG. 302.—Diagram of the Circuit-Changing Arrangements of a Typical Electrical Vehicle. The full lines in these plans indicate the closed, or active, circuits; the dotted lines the open, or inactive, circuits. As may be readily understood, the whole scheme of circuit-changing depends on employing several different circuit connections between battery and motor, which may be opened and closed, as desired. Here A and C are the lead wires between battery, B, and motor brushes, F F and G G, and the field-windings, H and J, and wire, D.

gives the lowest speed and power efficiency of the motors. By the wire, *D*, the current is carried to the brushes, *FF* and *GG*, which, according to this scheme, are permanently connected in multiple, the return path to the negative pole of the battery being through the wire, *A*.

In the second figure of the diagram the circuit is varied so as to connect the two units of the batteries, so as to give its highest pressure efficiency. But, since the field windings of the motors are also connected in series, or in series-parallel, as in this case, the efficiency in speed and power is reduced nearly one-half.

In the third figure the two units of the battery are connected in series, which, as in the former case, indicates the greatest efficiency in power output; but the field windings are connected in parallel, which means that the C. E. M. F., generated by their operation, is equivalent to the C. E. M. F. of only one motor, with the result that the speed and power efficiency is raised to its highest point.

**Diagram of Battery, Motor and Controller.**—In the second diagram, illustrating a typical method of shifting the circuits, we have the same general scheme applied, so far as the first, second and fourth speeds are concerned, the connections of the controller being laid out in rectangular form between the broken lines. When the controller is rotated, so that the row of terminal points, $A$, $B$, $C$, $D$, $E$, $F$, $G$, are brought into electrical contact with the row of terminal points, on the controller, $A'$, $B'$, $C'$, $D'$, $E'$, $F'$, $G'$, we have the first speed forward, which, as may be readily discovered by tracing the connections throughout, involves that the two-unit battery is connected into multiple and the field windings of the two motors in series. Tracing the connections indicated for the second speed, we see that the terminal points, $A$, $B$, $C$, etc., are brought into electrical contact with $A^2$, $B^2$, $C^2$, etc., and we have the batteries in multiple and the fields in series-multiple. Tracing the connections indicated for the third speed, we have the terminal points, $B$ and $C$, connected to the terminal points, $B^3$ and $C^3$, and the terminal points, $E$ and $F$, connected to the terminal points, $E^3$ and $F^3$, which means that the batteries are connected in series and the fields in series. Similarly, by tracing the connections for the fourth speed, we find the terminal points, $B$ and $C$, connected to terminal points, $B^4$ and $C^4$, and the terminal points, $D$, $E$, $F$, $G$, in electrical connection with the terminal points, $D^4$, $E^4$, $F^4$, $G^4$, which means that the batteries are in series and the fields in multiple. The connections between the battery, the armature brushes and the motor fields, are made as indicated through the

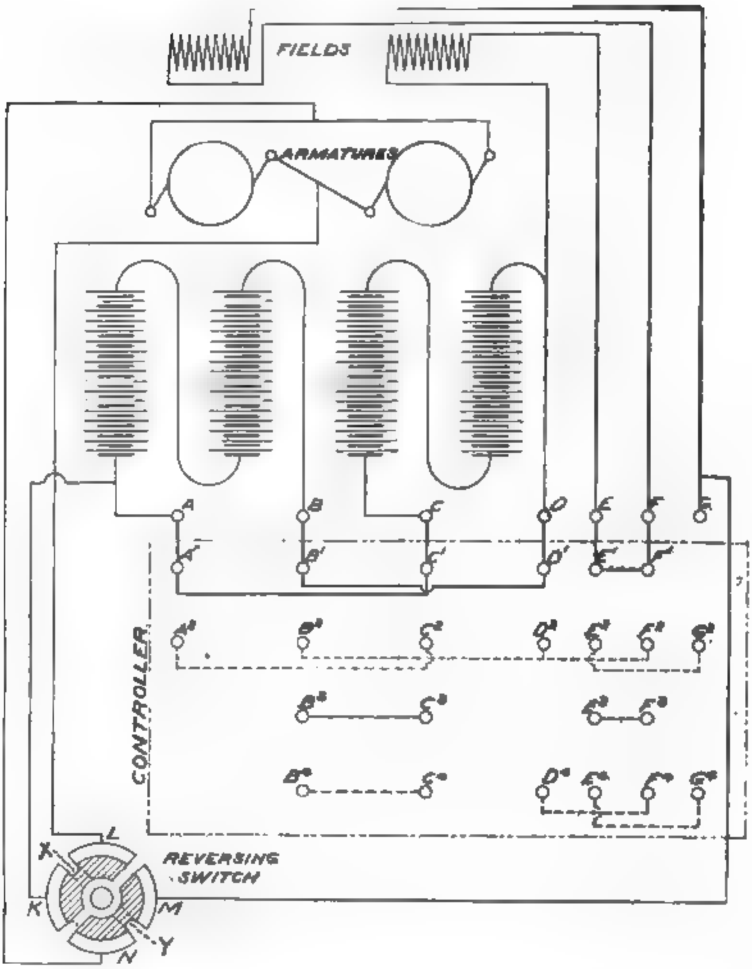



FIG. 303.—Diagram Plan of the Several Parts of an Electrical Vehicle Driving Circuit. The field-windings and armatures are shown projected, the proper wiring connections being indicated. The periphery of the controller is laid out within the broken line rectangle, the contacts and connections through it for varying the circuits through four speeds being shown. A, B, C, D, E, F, G are the terminal contact points of the various speed circuits, to be made as the positions of the controller contacts are varied A′, B′, C′, D′, E′, F′ are the controller contacts, which, with those already mentioned, make the proper circuits for the first speed. Similarly, $A^2$, $B^2$, $C^2$, etc., when brought into contact with A, B, C. etc., give the second speed circuits; $B^3$, $C^3$, $E^3$, $F^3$, in contact with A, B, C, D, etc , give the third speed; and $B^4$, $C^4$, $D^4$, in the same manner, the fourth speed. The reverse switch gives the backward movement, as described.

rotary reversing switch, by the terminals, *K, L, M, N*. This switch may effect the reversal of the motors by giving a quarter turn to its spindle, which means that the contacts of segment, *X*, will be shifted from *L* and *K* to *K* and *N*, and the contacts of segment, *Y*, shifted from *M* and *N* to *L* and *M*, thus reversing the direction of the current.

**Electric Vehicle Company's Circuits.**—Some leading manufacturers of electric vehicles, notably the Electric Vehicle Co.,

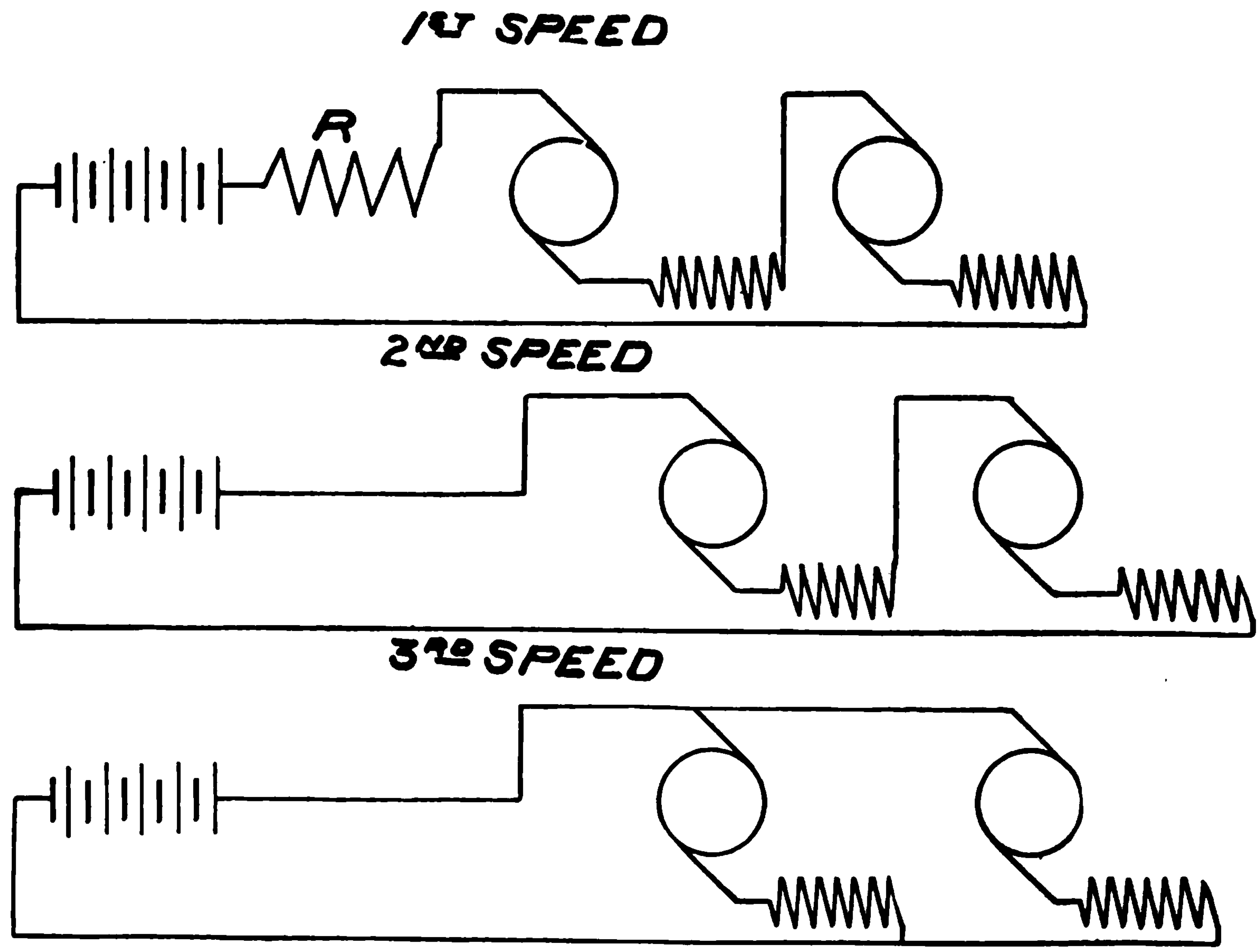



FIG. 304.—Diagram of a Typical One-Battery-Unit, Two-Motor Circuit. The first speed shows the two motors *in series*, with a resistance coil interposed; the second, the motors *in series*, without the resistance; the third, the motors *in multiple*.

vary the scheme shown in the last two figures by connecting the armature brushes and fields of each motor into series, and shifting the circuit connections, where two motors are used, from series to series-parallel. In the figure showing the combination of one battery unit with two motors, the connections for the three speeds obtained are obvious. Since only one unit is used, the lowest pressure of the battery can be obtained only by inserting a resistance coil, *R*, in the circuit, with the armature brushes,

field windings and both motors connected in series. For the second speed the resistance is simply cut out, allowing the full voltage of the battery to pass through the armatures and windings of both motors, still connected in series. For the third speed the connections of armatures and motors are shifted to multiple, or series-multiple. With the use of a two-unit bat-

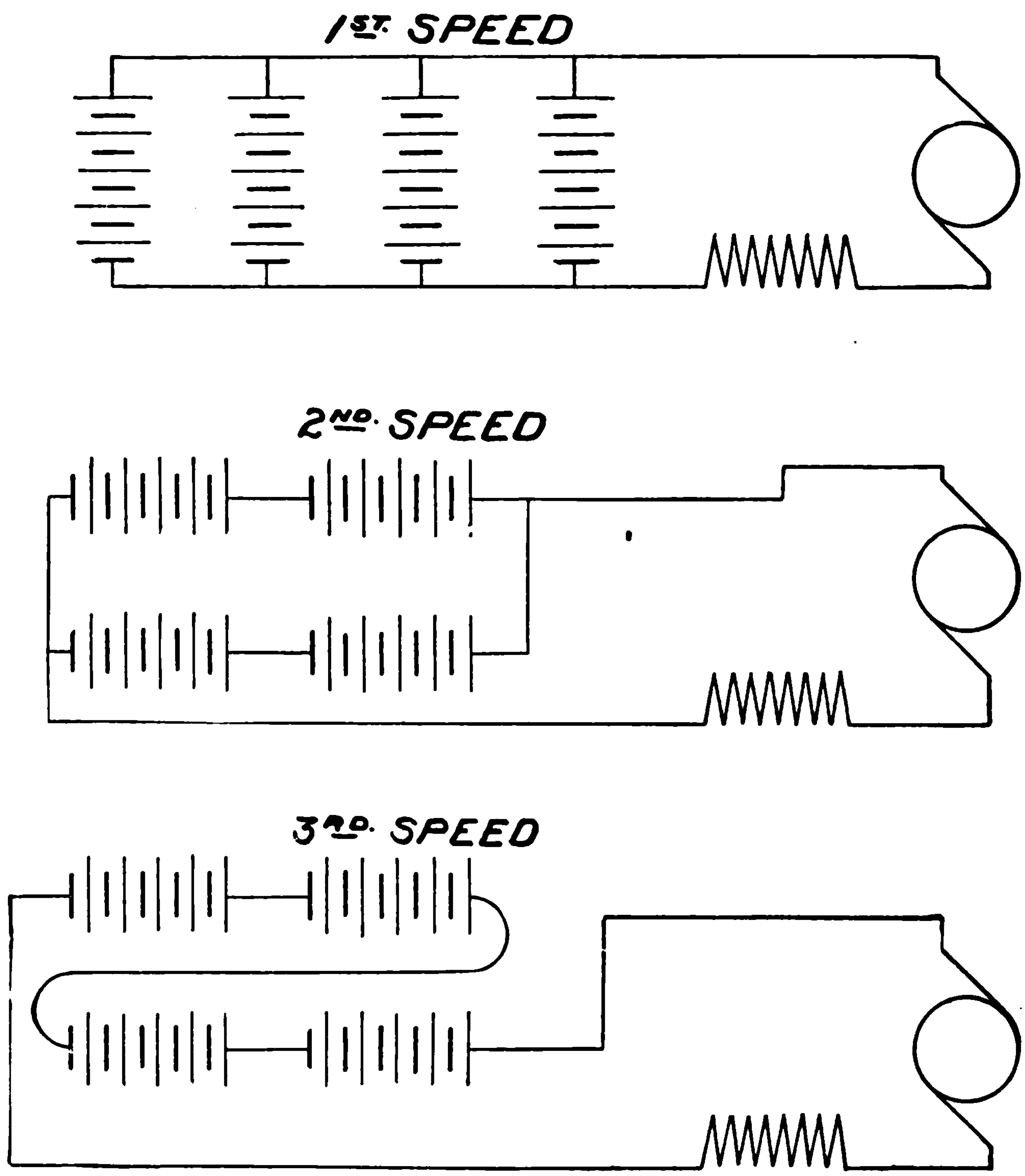



FIG. [illegible]5.—Diagram of a Typical Four-Battery-Unit, Single-Motor Circuit, showing combinations for three speeds. The only changes made in these circuits are in the battery connections. For the first speed the battery units are *in multiple;* for the second, *in series-multiple;* for the third, *in series.* The motor connections are not varied.

tery and two motors, it is possible to eliminate the resistance coil altogether and depend entirely upon circuit shifting regulating the voltage and power. Accordingly, for the first speed we have the batteries connected in multiple, and the armatures and windings of the two motors in series. For the second speed,

the series connections are adopted for both batteries and motors, while for the third speed the batteries are in series, with the motors in parallel.

**A Four-Battery-Unit, One-Motor Circuit.**—In the diagram indicating the use of four-battery-units with one motor, which, as shown in an accompanying cut, is used to drive both rear wheels of the wagon through a single reduction, it is possible to obtain

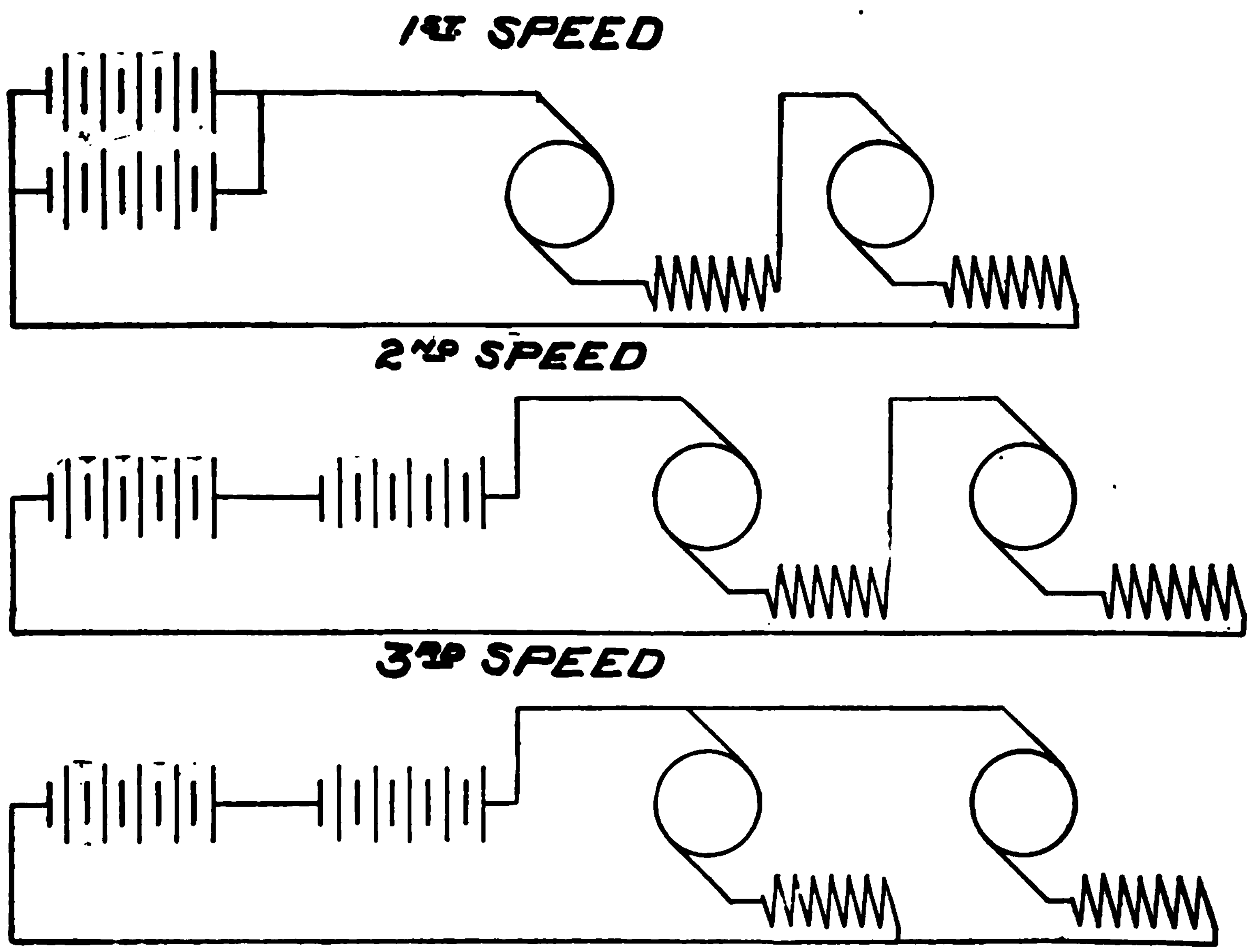



FIG. 306.—Diagram of a Two-Battery-Unit, Two-Motor Circuit, showing combinations for three speeds. The first speed is obtained with the battery units *in multiple*, and the motors *in series*; the second, with the battery units *in series*, and the motors *in series*; the third, with the battery units *in series*, and the motors *in multiple*.

a still greater range of variation by the simple shifting of the battery circuits, without alteration of the armature or field connections. Accordingly, for the first speed we have the four units connected into parallel, which gives a total voltage equivalent to the voltage of any one of them. For the second speed, the battery units are connected into series, the two pairs thus formed being joined in multiple, with the result that the total voltage of the battery is equivalent to the sum of the voltage of two of the

units, or twice the voltage used in the first speed. For the third speed, all four units of the battery are connected into series, thus doubling the voltage again, and realizing the highest speed and power efficiency possible in the combination.

**Vehicle Circuit Arrangements.**—The next two figures illustrate different methods of arranging the circuits of an electric

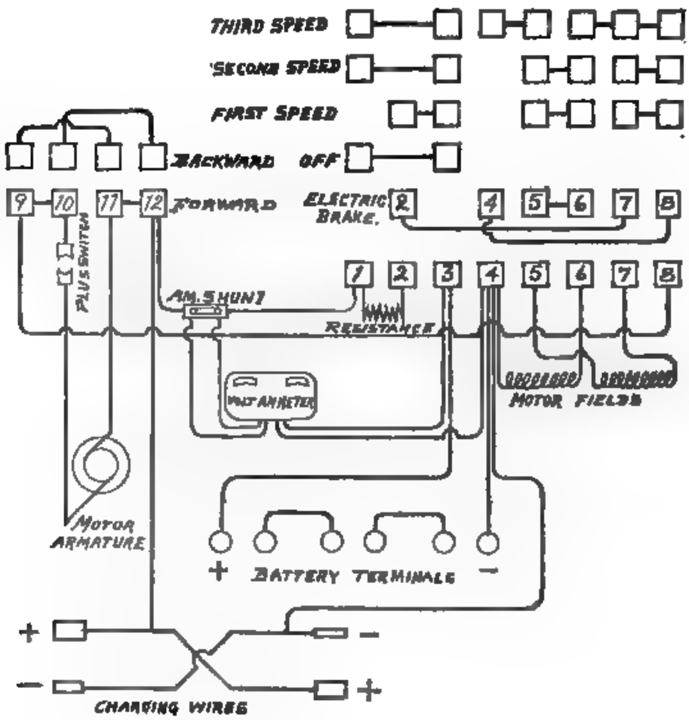



FIG. 307.—Diagram of Controller Connections of a One-unit, One-motor Circuit, with Variable Fields.

vehicle in actual practice. In the first, which shows the arrangements used on light Waverley carriages, the one-unit battery in three trays is shown connected in an invariable series circuit, giving the first, or lowest, speed through the resistance coil between controller contacts, 1 and 2, the motor-fields being in series; the second speed with the same circuit without the re-

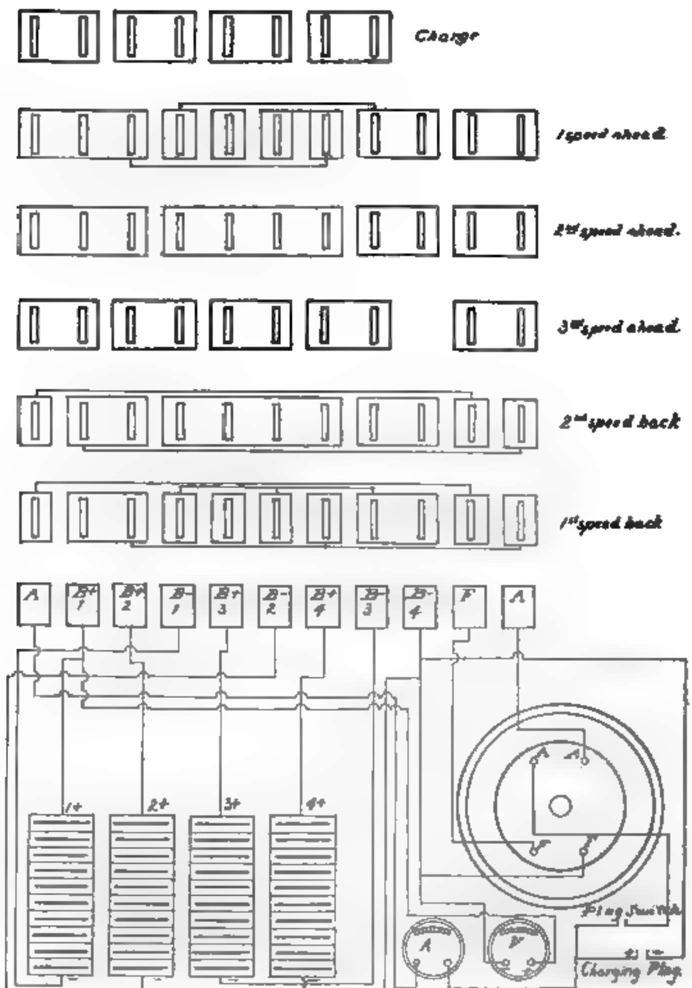



FIG. 308.—Diagram of Controller Connections of a Four-unit, One-motor, Circuit, with Constant Series Connections for Fields and Armature in Forward and Backward Speeds.

sistance, and the third speed with the motor-fields in parallel. The motor used on these carriages is of the six-pole type, the field coils being divided into two halves of three coils each, each half being independently connected to the controller contacts, as shown in the cut. Reversal is by a form of rotatable switch, and an electric brake is also used, which operates on the principle of reversing the polarity between the armature and field windings. In the second diagram is shown the connections of a series motor, in which the field and armature windings are in invariable series connections for all forward speeds. The first, or lowest, speed forward is obtained with three units of the bat-

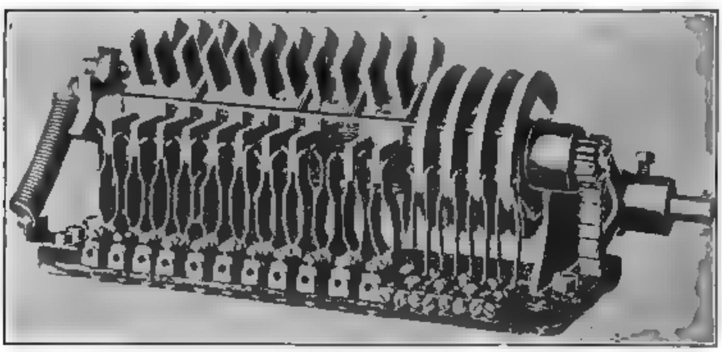


FIG. 309.—A Typical Electrical Vehicle Controller, or Circuit-changing Switch. The circuit terminals of battery and motors are shown at the jack-springs, which are arranged to be engaged by the fins on the periphery of the controller-cylinder. The connections within the controller, between the fins, are the same as those shown in Fig. 308, except for the fact that the four rings at the right hand end provide constant voltage connections for use with a shunt motor. The gaps at the rear of the rings show means for cutting out the shunt field at top speed.

tery in series-multiple; the second, with the four units in series-multiple; the third, with the four units in series. In reversing, the first and second speeds backward correspond to the forward speed arrangements similarly numbered, with the exception that the connections of field and armature are reversed, as may be readily understood from following out the indicated connections. In the charging position, the three contacts at the right side of the controller are cut out, leaving the battery to be charged in series from the charging plug connections to contact, *A*, at the left of the controller, to the similar connections with the negative pole of battery, 4.

**The Controller of an Electric Vehicle.**—The controller of an electric vehicle consists of a rotatable insulated cylinder, carrying on its circumference a number of contacts, arranged to make the desired connections with the terminals of the various apparatus in the circuit through a wide range of variation. As shown in the figure of the arrangement of the battery and controllers in a typical electric vehicle, these points are disposed so that the units of the battery may be connected in series or multiple, and that the field windings of the motors may be similarly varied. As shown in the diagram, this act is accomplished by a series of variations of electrical connection among the contact points on the periphery of the controller. Thus we find that

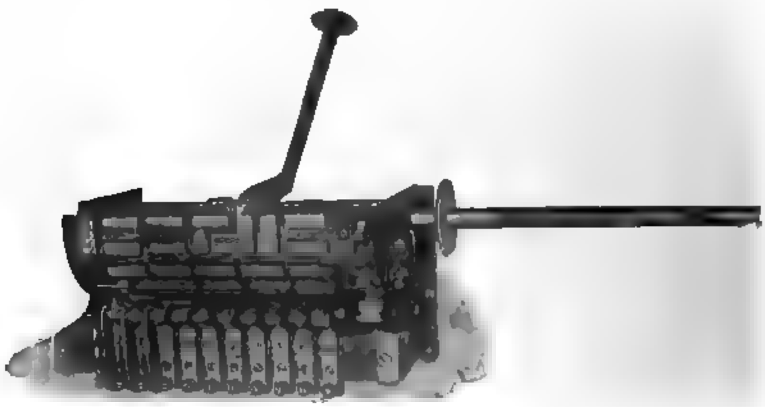


FIG. 310.—Typical Controller of the General Electric Co., showing means for making circuit connections through conducting segments on the periphery of the controller-cylinder.

for the first speed, in which the batteries are connected in multiple, the points, *A'*, *C'*, are in electrical connection, as indicated by the lines between them, so that the points, *A*, *C*, connected to the like poles of the two battery units, are directly connected, thus bringing the two units into multiple. The battery circuit is completed by the electrical connection on the controller between the points, *B'* and *D'*, when they are brought into contact with the points, *B* and *D*, which connect to the two other poles of the battery. Furthermore, the points, *E'* and *F'*, being in electrical connection through the body of the controller, connect points, *E* and *F*, direct, thus throwing the field windings of the

motors into series. As may be understood from the last two diagrams of vehicle circuits, the contacts may be arranged to make any of several schemes of circuit variation, although, as must be obvious on examination, a specially arranged controller is necessary for each separate scheme.

**Construction of a Controller.**—The accompanying cuts show the general appearance and construction of several types of controller for electrical vehicles. As may be seen in the first cut,

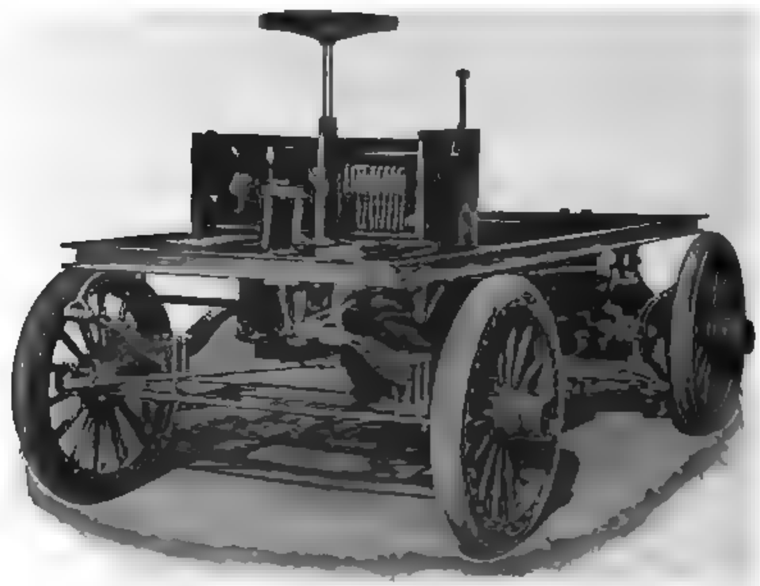


FIG. 311. Chassis of a Heavy Wagon of the Electric Vehicle Co., showing arrangement of controlling apparatus.

the connections of the terminals of the batteries, of the field windings, and other elements of the circuit, are made at the binding posts at the front base of the instrument. From each of these binding posts, which are electrically insulated from one another, jack-springs rise to a position convenient to make connections with the switch blades arranged along the periphery of the controller cylinder. These switch blades, as may be seen, are secured to the controller cylinder by screw connections, be-

ing arranged singly, or several of them together on one plate. In the case of a pair of blades, shown in contact with the spring at either extremity of the controller cylinder, it is evident that there is an electrical contact, through the base plates, between the two terminals, represented by the contact springs in engagement. Between these two end plates, as may be seen, there are several switch blades arranged singly upon the circumference. At one point there is no contact whatever, showing that the terminals represented by the contact springs at that point are out of circuit. These several blades that are arranged singly on the controller surface have such electrical connections as the scheme of circuit variation adopted demands, made through insulated wire connections arranged between any pair it is desired to connect. This is the arrangement indicated in the diagram of connections already described. It is perfectly easy to understand, therefore, how the circuit arrangements of battery units and motor windings may be varied through any desired range of connections, by simply connecting their terminals through properly arranged and connected controller contacts.

**Varieties of Controller.**—The controller shown in the cut, already described, represents only one type of this machine. Some controllers are constructed simple, with a perfectly cylindrical surface, upon which bear single leaf springs, the desired electrical connections being made by suitably connected conducting surfaces on the cylinder circumference, and cut-outs being similarly accomplished by insulating surfaces, bearing against the spring contacts at the desired points. This type of controller is shown in the second cut, and is one of the most usual forms for motor vehicle purposes. As is perfectly obvious, it is possible to so arrange the electrical connections on the controller surfaces, that by proper contacts with the terminal springs, reversal of the motor may be accomplished, as shown on the last circuit diagram. This is done in a number of controllers, the reverse being accomplished at a definite notch on the quadrant of the shifting lever.

## CHAPTER THIRTY-SEVEN.

### THE CONSTRUCTION AND OPERATION OF STORAGE BATTERIES.

**Storage Cells Not Condensers.**—As already stated, electric vehicles derive their power from storage batteries, which are charged from a suitable charging plant, supplying current either from the street power lines, or from the dynamo operated by any convenient source of power. The word, storage battery, as applied to electrical accumulators, or secondary batteries, is somewhat of a misnomer, since these devices are in no sense receptacles for electrical energy, and act on an entirely different principle from the instrument known as a condenser, which depends solely upon such variations of the electrical potential between two surfaces, that one of them may be so affected by the electrical current, momentary or prolonged, as to give forth electrical energy in the form of a shock, when brought into contact with any other surface having a low or negative potential. Such a device as this is, of course, useless for any purpose requiring a constant current between two points of different potential, such as is required for any kind of power transmission.

**Cells, Primary and Secondary.**—The so-called electrical accumulator, or storage battery, more properly to be described as a secondary battery, operates on an entirely different principle, to be briefly described as an electro-chemical, by which a direct electric current, steadily flowing through a given period, can produce certain chemical changes, which, as the expression is, "charge" the battery. This process may be briefly illustrated by making a comparison with a primary galvanic cell. In such cells two electrodes of dissimilar substances, such as copper and zinc, or carbon and zinc, are immersed in a liquid solution, in the first case of dilute sulphuric acid, in the second of sal ammoniac—although different solutions are used in the various makes of cells. As soon as the two electrodes, thus immersed in the liquid, are connected by a wire outside of the solution, so as to form a complete circuit between them through the liquid and back again through the outside wire, an electrical current, which is to say,

a continuous transmission of electrical energy, is set up. This phenomenon takes place in accord with what may be called the specific potential of the two metals. This means that if two such substances, copper and zinc, or carbon and zinc, be brought into contact *in the air,* there will be a distinct impartation of energy from the former to the latter in each case, showing that carbon and copper receive and give off a charge much more readily than zinc. On the other hand, when two such substances are immersed in the electrolytic solution the conditions are completely reversed, the impartation of energy *through the liquid* being *from* the zinc to the copper or carbon. Thus, the typical galvanic cell is really a combination of the phenomena taking place both in air—on the outside wire, between the portions of the two plates not wet with solution—and through the electrolyte. This renders the galvanic circuit possible. It also explains the fact that the zinc, or positive plate in the solution, is the negative terminal of the outside wire.

**The Operation of a Galvanic Cell.**—In an assembled galvanic cell of any type the operations taking place before the circuit of the outside wire is closed are purely chemical; only when the circuit is closed does electrical energy begin to manifest itself in the form of current. The same chemical processes then continue, with the result, however, of doing useful work. The first result of closing the circuit is the decomposition of the electrolyte into its component parts. If it is dilute sulphuric acid ($H_2\ SO_4$), the decomposition is into hydrogen, oxygen and sulphuric oxide—the oxygen uniting with the zinc and gradually consuming it, and the hydrogen being collected on the face of the copper plate in the form of minute bubbles. In practical cells it is necessary to use some substance, known as the "depolarizer," that has a high affinity for hydrogen, in order that the hydrogen may be constantly absorbed and the process allowed to continue until the zinc is exhausted. Were it possible to "restore" a primary chemical cell, so that the zinc oxide would again become metallic zinc, and the electrolyte be re-composed from its elements, we would have a very fair duplication of the conditions theoretically found in a secondary, or storage, cell—except for the fact that in the latter the processes taking place on the outside wire are the same as those occurring in the electrolyte in the

primary, and *vice versa*. This means that the hydrogen collects on the plate connected to the negative lead, while the destructive chemical changes occur in that connected to the positive lead of the outside circuit.

**The General Theory of Storage Batteries.**—The general theory upon which a secondary battery operates was discovered as early as 1801, when Gautherot discovered that if two plates of platinum or silver, immersed in a suitable electrolyte, are connected to the terminals of an active primary cell and current is allowed to flow for any desired period, a small current could be obtained on an outside circuit connecting these two electrodes, as soon as the primary battery had been disconnected. The process which takes place in this case is briefly as follows: An electrolyte, consisting of a weak solution of sulphuric acid, permits ready conduction of the current from the primary battery, the greater the proportion of acid in certain limits the smaller being the resistance offered. The effect of the current passing through the electrolyte is the decomposition of the water, which is indicated by the formation of bubbles upon the exposed surfaces of both electrode sheets, these bubbles being formed by oxygen gas on the plate connected to the positive pole of the primary battery, and hydrogen on the plate connected to the negative pole of the battery. Because, however, the oxygen is unable to attack either platinum or silver under such conditions, the capacity of such a device to act as an electrical accumulator is practically limited to the point at which both plates are covered with bubbles. After this point the gases will begin to escape into the atmosphere. In this simple apparatus, as in the storage cells manufactured at the present day, the prime condition to operation, is that the resistance of the electrolyte should be as low as possible, in order that the current may pass freely and with full effect between the electrodes. If the resistance of the electrolyte is too small, the current intensity will cause the water to boil rather than to occasion the electrolytic effects noted above.

As soon as the current from the primary cell is discontinued, and the two electrode plates from the secondary cell are joined by an outside wire, a small current will be caused to flow upon that outside circuit by the recomposition of the acid and water solution. The process is in a very definite sense a reversal of

that by which the current is generated in a primary cell. Hydrogen collected upon the negative plate, which was the cathode, so long as the primary battery was in circuit, is given off to the liquid immediately surrounding it, uniting with its particles of oxygen and causing the hydrogen, in combination with them, to unite with the particles of oxygen next adjacent, continuing the process until the opposite positive plate is reached, when the oxygen collected there is finally combined with the surplus hydrogen, going to it from the surrounding solution. This chemical process causes the current to emerge from the positive plate, which was the anode, so long as the primary battery was in circuit. The current thus produced will continue until the recomposition of the gases is complete; then ceasing because these gases, as before stated, do not combine with the metal of the electrodes.

**Requirements in a Practical Storage Battery.**—In order to produce a secondary battery that shall be able to give forth a current of sufficient strength and duration for practical purposes, it is necessary to employ some metal that can be attacked by the oxygen produced in the process of "charging," but which at the same time is capable of being restored to its normal condition when the operation is reversed and current is taken off from the cell. Hitherto, the substance found most suitable for this purpose has been lead, which, until the perfection of Edison's iron-nickel cell, has been in practically universal use for the plates and grids of storage batteries. Of course, under operative conditions, the restoration of the metal is not perfect; also, continual chargings and dischargings inevitably result in the breaking-down of the plates, involving that they be replaced.

**The Planté Secondary Cells.**—About 1860 Gaston Planté, a French electrician, perfected the first practical storage cell constructed by folding together spirally two sheets of metallic lead, separated by a thin septum of canvas or a strip of gutta percha and immersed in a weak solution of sulphuric acid. When a current from a primary battery is passed through the electrolyte between the two lead sheets, the same process takes place as was described in connection with Gautherot's primitive platinum cell. Oxygen and hydrogen, liberated by electrolysis, collect upon

the surface of the plates, thus forming the electro-chemical basis for the production of a current, so soon as the primary electrical source is disconnected. The operation differs, however, from that formerly noted, in the fact that oxygen bubbles do not appear upon the surface of the anode, but effect a chemical change

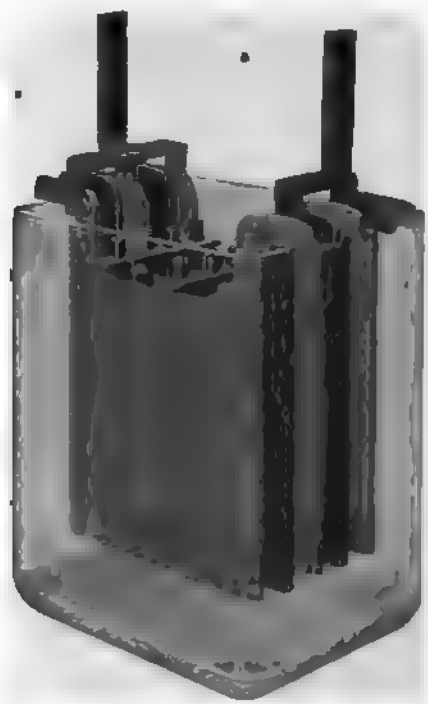


FIG. 312.—A Typical Storage Cell Enclosed in a Glass Jar. This cell represents one of the best-known makes of the Planté genus. With five plates, as shown, such a cell has a capacity of 80 ampere-hours, at 8 hours' discharge; of 70 ampere-hours, at 5 hours' discharge; of 60 ampere-hours, at 3 hours' discharge, with a discharge rate of 10 amperes in 8 hours, of 14 amperes in 5 hours, and of 20 amperes in 3 hours. The total outside dimensions of this cell are 5⅛x9½x11¼ inches; dimensions of each plate's active surface, 7¼x7¾ inches.

in the plate. The oxygen attacks the lead, forming lead peroxide. By disconnecting the primary source a weak current can be produced from this cell, until the normal conditions have been restored, as previously explained; but, in order to fit it for any kind of practical use, it must be suitably "formed," which process

originally consisted in applying a charging current, first in one direction, then in the other, and allowing a discharge to follow in each case. In this process, which should occupy about two months, the following series of changes take place: The lead peroxide collected on the surfaces of one of the sheets, gradually disappears, as detected by the change in the color from brown to lead metallic. The peroxide, however, gradually begins collecting on the surface of the other plate, and so continues so long as the current endures. A plate from which the peroxide has been separated, by repeated alternations of the charging current, assumes a spongy character, which enables the augmentation of its electrical accumulating property by increasing the surface exposed to the attacks of the oxygen gas. This process of "forming" by repeated alternations of the charging current, produced a high standard of efficiency; the average power output of the earlier types of the Planté cell having been 7¼ ampere-hours per pound of lead, which is as good as has since been achieved. However, it rendered the plates very nearly rotten by the time the maximum capacity had been achieved. As a consequence the later types of this variety of cell are composed of plates formed by pickling baths of 50 per cent. solution of nitric acid. After an immersion of from 24 to 48 hours in this solution, they are treated with a 10 per cent. solution of sulphuric acid, or by a thorough washing in ammonia, followed by heating in a furnace to a temperature of 203 degrees Centigrade. Other processes, generally of a secret nature, are also used to further prepare the plates. After this they are in a condition to be used in a practical secondary battery, the process and conditions of charging being essentially the same, as have already been described.

A typical American storage cell of the Planté genus is shown in the several accompanying illustrations, which serve to show the essential features of this variety of accumulator. Both the positive and negative plates are constructed with a large number of deep parallel grooves, cut by means of a special tool. This process is termed "spinning." In order to "form" the battery the plates, thus suitably grooved, are placed in a strong oxidizing solution, generally ammonia nitrate, after which the current is passed through the solution transforming the oxides into peroxides. This treatment is continued until the entire space between the leaves is filled with active material. The formed plates

are reformed as negatives to cast off nitrates, then washed as a further protection against nitrates. Plates intended for positives are reformed in a sulphuric acid electrolyte. After these processes, the positive and negative plates may be assembled into cells, the necks being burned on, so as to connect each one to its respective terminal, the cells formed by a number of these plates —an odd number of positives and an even number of negatives—have sheets of porous hard rubber between each pair of plates.

With batteries of this make, intended for use in electric vehicles, a voltage output of from eight to ten watts per pound

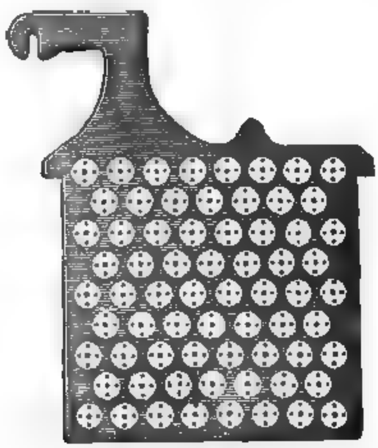


FIG. 313.—One Plate, or "Grid," of a Type of Storage Cell constructed by inserting buttons or ribbons of the proper chemical substances in perforations. Some such cells use crimped ribbons of metallic lead for inserting in the perforations, others pure red lead or other suitable material

of total battery weight may be realized. The duration of its period of usefulness is also considerably longer than that realized in many other types of cell, which is a quality claimed for several of the most representative batteries of the Planté genus.

**The Faure Secondary Cells.**—The Faure cells, first invented in 1881, differ from the original Planté variety in the fact that the process of forming is largely done away by "pasting," or applying active material directly to the surfaces of the plates, or "grids," in pockets or perforations. This involves that the lead

grids be specially prepared for the purpose, and designs in large variety, intended to increase the active surface, while maintaining the strength of the structure, have been used by as many different inventors and manufacturers. One trouble with many such pasted cells has been that the grids are heavy in proportion to the amount of active surface exposed, and, that they are liable to warp or buckle, allowing portions of the active substance to fall between adjacent plates, short-circuiting the cell. The substances most often used in the Faure type of cell are *minium* or red lead oxide ($Pb_3 O_4$) and lead monozide or *litharge* ($Pb O$). The former under the action of the electrolyte becomes the so-called "red lead salt," the latter, the "buff lead salt." Some cells using grids with perforations for holding the active material are made somewhat differently. Thus, as stated by several authorities, in a type of cell widely used in America the positive plates or "grids" are composed of an alloy of lead and antimony, cast into shape with a certain number of round perforations. Each of these holes is then filled with a button, made by rolling a crimped lead ribbon into a coil of proper size to fit it tightly. By an electro-chemical process, the required lead oxide is then produced. The negative grids are made of casting the proper shape, under heavy pressure, around a number of square blocks of fused chloride of zinc and chloride of lead. When the grid is completed, the zinc is chemically removed, leaving the contents of each perforation pure spongy lead. The plates are now ready to be assembled into a cell and to begin work as soon as the current has passed through the electrolyte composed of a solution of sulphuric acid. Cells specially adapted for automobile work are produced by the same manufacturers.

The series of operations taking place during the charge or discharge of a storage cell are very complicated, and need not be fully discussed at the present time. It is desirable, however, to outline them in a general way. In discharging a cell the oxygen in the electrolyte attacks the spongy surface of each negative plate, releasing hydrogen, which, in turn, reduces the lead peroxide or dioxide ($PbO_2$) of each positive plate to monoxide ($Pb O$). The surplus radical of the acid then combines with the active material on both plates, producing sulphates and thus reducing the specific gravity of the electrolyte. Although this "sulphating" of the plates is a common and necessary part of the

process of discharge, it is a source of trouble, if allowed to become excessive, as in an overdischarge—below 1.8 or 1.75 volts. In charging, the current passes from the each positive plate through the electrolyte to the negative, exerting the effect of decomposing the sulphate and transferring all the oxygen from the negative to the positive plates. The negative plates are thus freed from oxide, becoming merely spongy or porous metallic lead; while the positive plates contain no oxides lower than the peroxide, with the probable addition of some sulphates. Owing to the decomposition of the sulphates, the specific gravity of the electrolyte is at its highest on completion of the charge. The limit of charging capacity is carefully determined for each type of cell, but may be readily recognized by the giving-off of oxygen and hydrogen gases. The condition of the plates may also be known by their color. Thus, at full charge the positives are dark brown and the negatives, dark slate colored; at discharge the positives are chocolate brown and the negatives, light slate colored. The specific gravity of the electrolyte also gives an indication on this point, as above suggested. Sulphating and over-discharge are indicated by a drab color of the positive plates.

Considering only the reactions that affect the active materials, we have the following formulæ, as given by several authorities:

In charging

POSITIVE PLATES.

$$PbSO_4+SO_4+2H_2O=PbO_2+2H_2SO_4.$$

NEGATIVE PLATES.

$$PbSO_4+2H=Pb+H_2SO_4.$$

In discharging

POSITIVE PLATES.

$$(1)\quad PbO_2+2H=PbO+H_2O.$$

$$(2)\quad PbO+H_2SO_4=PbSO_4+H_2O.$$

NEGATIVE PLATES.

$$Pb+H_2SO_4=PbSO_4+2H.$$

Combining these equations, we have the "practical universal equation," as given by several authorities:

$$PbO_2+2H_2SO_4+Pb=2H_2O+2PbSO_4.$$

This means simply that a combination of lead peroxide (1 part), metallic lead (1 part), sulphuric acid (2 parts), gives, in process of discharge, water (2 parts) and lead sulphate (2 parts)—the process being reversed during charging.

For a cell previously charged, and using red lead salt as the active material, the following series of changes are given by Frankland and quoted by other authorities:

In charging

POSITIVE PLATES.

$$S_2Pb_3O_{10}+O_2+2OH_2=3PbO_2+2SO_4H_2.$$

NEGATIVE PLATES.

$$S_2Pb_3O_{10}+4H_2=3Pb+2SO_4H_2+2OH_2.$$

In discharging

POSITIVE PLATES.

$$3PbO_2+2SO_4H_2+2H_2=S_2Pb_3O_{10}+4OH_2.$$

NEGATIVE PLATES.

$$3Pb+2SO_4H_2+2O_2=S_2Pb_3O_{10}+2H_2.$$

**Points on Care and Operation.**—On the manner of operating and maintaining storage batteries for use in electric vehicles and for other purposes, there are a number of points to be considered.

However, since full directions are always furnished by manufacturers with each set of cells, it is necessary to give only the merest outlines here. Nearly the most important matter for the beginner to understand thoroughly is that relating to the preparation and use of the electrolyte. As has been already stated, this consists of 1 part of chemically pure concentrated sulphuric acid mixed with several parts of water. The proportion of water differs with the several types of cell from 3 parts to 8 parts, as specified in the directions accompanying the cells. In making the mixture it is necessary to use an hydrometer to test the specific gravity of both the acid and the solution. The most suitable acid should show a specific gravity of about 1.760, or 66° Baume.

The mixture should be made by pouring the acid slowly into the water, never the reverse. As cannot be too strongly stated,

*it is very dangerous to pour the water into the acid,* and too much care cannot be exercised on this point. The reason is that great heat is generated when the water and acid come into contact, and an explosion is more than likely to be the result. Since concentrated sulphuric acid—popularly known as oil of vitriol—is immensely corrosive, it will burn the flesh painfully, disfigure the face and destroy the eyes. Therefore, a person unskilled in chemistry should handle it with the greatest care, and *only in ac-*

FIG. 314.—"Unformed" Plate of One Pattern of "Gould" Storage Cell. The particular plate shown has total outside dimensions of 6x6 inches. The clear outline of the grooves indicates absence of oxides, due to action of "forming" solutions, or charging current.

*cordance with directions.* Care should always be taken that the water used is pure as possible, distilled water or rain water being preferable. River and well water should never be used for this purpose, since it contains certain salts of chlorine and ammonia, which are apt to seriously affect the plates and shorten the life of the battery.

When made the solution should be allowed to cool for several hours or until its temperature is approximately that of

the atmosphere (60° being the average). At this point it should have a specific gravity of about 1,200 or 25° Baume. If the hydrometer shows a higher reading, distilled water may be added until the correct reading is obtained; if a lower reading, dilute acid may be added with similar intent.

The electrolyte should never be mixed in jars containing the battery plates, but preferably in stone crocks, specially prepared for the purpose. Furthermore, it should never be placed in the cell until perfectly cool.

As soon as possible after placing the electrolyte in the cell, the charging current should be applied. In other words, the electrolyte should not be placed in a new cell until it is time to charge it. If this is not done, the acid solution will act upon the plates, producing sulphates of lead, and with pasted cells virtually insulating the active material from the metal of the grids, which is an extremely difficult condition to remedy.

For precisely similar reasons, a battery should be maintained at as near full charge as possible, particularly when used irregularly and allowed to stand idle for periods between times of operation. After a long run, when almost exhausted, recharging should be begun as soon as possible. A battery should never be allowed to "rest," unless it is disassembled and its elements are dried and treated according to directions furnished by the makers. By observing these rules carefully, the life of the apparatus may be lengthened and its usefulness unimpaired by sulphating and other causes of imperfect operation.

**Short-Circuiting.**—A form of derangement that may occasionally affect the vehicle batteries is short-circuiting. It may be caused by some of the active material—if the cell is of the pasted variety—scaling off and dropping between the plates, or by an over-collection of sediment in the bottom of the cell. If by any means, also, a solid conducting foreign substance should fall between the plates when the cell is opened, that is sufficient to cause the difficulty. Should the operator suspect trouble with his battery, he may discover a short-circuited cell by the marked difference in color of the plates or of the specific gravity of the electrolyte, as compared with the other cells. No particular damage will be caused, if the trouble is discovered and removed before these symptoms become too marked. If a foreign substance has

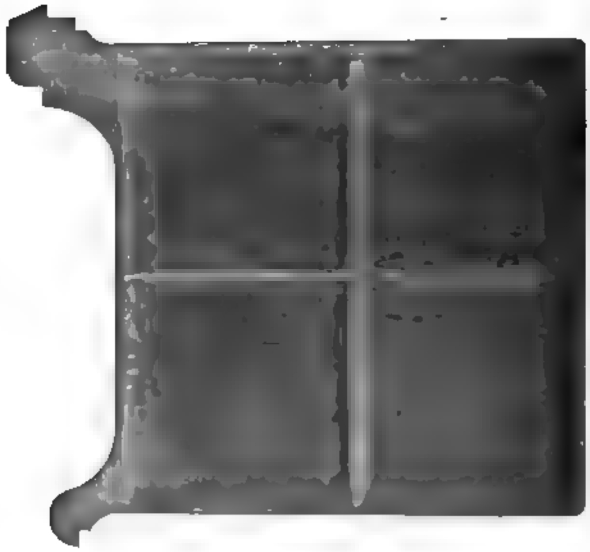


FIG. 315.—Specimen Negative Plate of a Type of the "Gould" Storage Battery, showing the result of "formation" in the changed appearance of the plate surface.
FIG. 316.—Specimen Positive Plate of a Type of the "Gould" Storage Battery, showing the changed appearance of the plate surface, due to "formation."

become lodged between the plates, it may be removed by a wood or glass instrument. If some of the active material has scaled off, it may be forced down to the bottom of the jar. If excessive sediment is found, the jar and plates should be washed carefully, and reassembled. A cell that has been short-circuited may be disconnected from the battery and charged and discharged several times separately. This may remedy the trouble.

In placing the electrolyte in jars containing the cells, special care should be taken that the entire active surface of the grids is completely submerged. They should always be at least one-half inch below the surface of the solution. Whenever it is necessary to renew the electrolyte this rule should be observed, and so long as the batteries are in operation the level should never be allowed to fall below the points specified.

**Connections for Charging.**—In charging a storage battery, it is of prime importance that the connections with the generator be properly arranged. This means that the positive pole of the generator should be invariably connected to the positive pole of the secondary battery—which is to say, the pole which is positive in action when the current is emerging from the secondary battery, or the pole that is connected to the positive plates. As this is a matter of prime importance, the exact polarity of both generator and secondary battery terminals should be accurately determined before attempt is made to charge. An error in this particular will result in entire derangement of the battery and its ultimate destruction. In charging a storage battery for the first time it is essential that the current should be allowed to enter at the anode or positive pole at about one-half the usual charging rate prescribed; but after making sure that all necessary conditions have been fulfilled, it is possible to raise the rate to that prescribed by the manufacturers of the particular battery.

**Period of Charging a New Battery.**—With several of the best known makes of the American storage battery the prescribed period for the first charge varies between twenty and thirty hours. The manufacturers of a well-known cell of the Planté genus prescribe for the first charge half rate for four hours, after which the current may be increased to the normal power and continued for twenty hours successively.

The strength of current to be used in charging a cell should be in proportion to its own ampere-hour capacity. Thus, as given by several manufacturers and other authorities, the normal charging rate for a cell of 400 ampere hours should be fifty amperes; or one-eighth of its ampere-hour rating in amperes of charging current. Before closing the charging circuit it is essential that the voltage of the generator should be at least ten per cent. higher

FIG. 817.—One Cell of the "Gould" Storage Battery for Electric Vehicle Use. According to the data given by the manufacturers, this cell, containing four negatives and three positive plates, has a normal charging rate of 27 amperes; a distance rate of 22½ amperes for 4 hours; a capacity of 81 ampere-hours at 3 hours' discharge, and of 90 ampere-hours at 4 hours' discharge. The plates are each 5⅞x7¼ inches, and the total dimensions of the cell, enclosed in its rubber jar, are 2½x6¼x11 inches. Forty such cells are generally used for an average light vehicle battery.

than the normal voltage of the battery when charged. The fact that a storage cell is fully charged is evident by the apparent boiling of the electrolyte and a free giving-off of gas. It may also be determined by the voltmeter, which will show whether the normal pressure has been attained. At the first charge of the battery, the voltage should be allowed to rise somewhat above the point of normal pressure, but thereafter should be discon-

tinued at a specified point. At the first charging of a cell, when the pressure has reached the required limit, the cell should be discharged until the voltage has fallen to about two-thirds normal pressure, when the cell should again be recharged to the normal voltage (2.5 or 2.6 volts).

**Changed Specific Gravity of the Electrolyte.**—Another effect resulting from the first charging of a storage cell is a change in the specific gravity of the electrolyte. According to the figures already given, this should be about 1,200, when the solution is first poured into the cells. At the completion of the first charge, it should, on the same scale, be about 1,225. If it is higher than this; water should be added to the solution until the proper figure is reached; if it is lower, dilute sulphuric acid should be added until the hydrometer registers 1,225.

In charging a storage cell, particularly for the first time, it is desirable to remember that a weaker current than that specified may be used with the same result, provided the prescribed duration of the process be proportionally lengthened. The battery may also be charged beyond the prescribed voltage, ten or twenty per cent. overcharge effecting no injury occasionally; although, if frequently repeated, it seriously shortens the life of the battery.

Another point of importance touches the question of maintaining the charge of the battery. Even if the use is only slight, in proportion to the output capacity, the battery should be charged at least once in two weeks, in order to maintain it at the point of highest efficiency. About as often a battery should be charged at slowest rate, the charging current being adjusted to complete the charge only in twenty or thirty hours.

In charging a storage battery, it is essential to remember the fact that the normal charging rate is in proportion to the voltage of the battery itself. Thus, a 100-ampere-hour battery, charged from a 110 volt circuit, at the rate of ten amperes per hour, would require ten hours to charge, and would consume in that time an amount of electrical energy represented by the product of 110 (voltage) by 10 (hours), which would give 1,100 watts.

**The Capacity of Storage Batteries.**—The discharge capacity of a storage battery is stated in ampere-hours, and unless other-

wise specified, refers to its output of current at the 8-hour rate. Most manufacturers of automobile batteries specify only the amperage of the discharge at 3 and 4 hours. As there is no sure way for the automobilist to estimate the discharge-capacity of his battery, he is obliged to base such calculations as he makes on the figures furnished by the manufacturers. With the help of his indicating instruments—the voltmeter and ammeter—this is a comparatively simple matter, as may be understood from the following quotation:

"It is customary to state the normal capacity of a cell in ampere-hours, based upon the current which it will discharge at a constant rate for eight hours. Thus a cell which will discharge at 10 amperes for 8 hours *without the voltage falling below* 1.75 *per cell* is said to have a capacity of 80 ampere-hours. It does

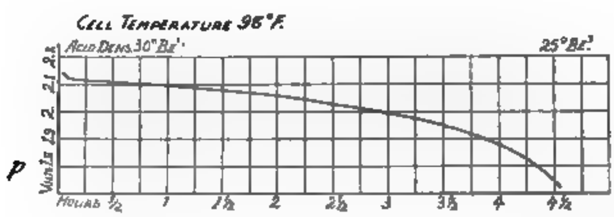



FIG. 318.—Discharge Curve of First Discharge in 4½ hours at 20 amperes of a 5 plate, [illegible]-inch cell used for ignition, showing very gradual fall in voltage through ⅔ of the period.

not follow that 80 amperes would be secured if the cell were discharged in 1 hour. It is safe to say that not more than 40 amperes would be the result with this rapid discharge. *The ampere-hour capacity decreases with the increase in current output.* An 80 ampere-hour cell, capable of delivering 10 amperes for 8 hours, would, when discharged at 14 amperes, have a capacity of 70 ampere-hours; when discharged at 20, its capacity would be 60; and when discharged at 40, its capacity will have decreased from 80 to 40 ampere-hours. Generally speaking, the voltage during discharge is an indication of the quantity of electricity remaining within the cell."

In order to obtain a general idea of the comparative figures, as between the several makes of American storage cell, the following tables on sizes suitable for automobile use are given.

The manufacturer of one of the most efficient types of battery gives the following data:

| Discharge in Amperes Per Hour During | | | Ampere Hour Capacity When Discharged in | | | Normal Charging Rate | Outside Dimensions of Jar in Inches | | |
|---|---|---|---|---|---|---|---|---|---|
| 8 Hrs. | 6 Hrs. | 3 Hrs. | 8 Hrs. | 6 Hrs. | 3 Hrs. | | Height | Length | Width |
| 6¼ | 8¾ | 12½ | 50 | 43¾ | 37½ | 6¼ | 10½ | 5¼ | 4¾ |
| 7½ | 10½ | 15 | 60 | 52½ | 45 | 7½ | 11 | 7⅜ | 4¾ |
| 8¾ | 12¼ | 17½ | 70 | 61¼ | 52½ | 8¾ | 12⅛ | 7⅜ | 4¾ |
| 10 | 14 | 20 | 80 | 70 | 60 | 10 | 12 | 6⅛ | 7 |
| 12½ | 17½ | 25 | 100 | 87½ | 75 | 12½ | 12 | 6⅛ | 7 |
| 15 | 21 | 30 | 120 | 105 | 90 | 15 | 12½ | 6⅛ | 7 |
| 17½ | 24½ | 35 | 140 | 122½ | 105 | 17½ | 12½ | 6⅛ | 7 |
| 20 | 28 | 40 | 160 | 140 | 120 | 20 | 12½ | 9⅛ | 5¾ |
| 22½ | 31½ | 45 | 180 | 157½ | 135 | 22½ | 12½ | 9 | 6½ |
| 25 | 35 | 50 | 200 | 175 | 150 | 25 | 12½ | 9 | 6½ |
| 27½ | 38½ | 55 | 220 | 192½ | 165 | 27½ | 12½ | 9 | 6½ |
| 30 | 42 | 60 | 240 | 210 | 180 | 30 | 12½ | 9 | 6½ |
| 37½ | 52½ | 75 | 300 | 262½ | 225 | 37½ | 12½ | 9⅛ | 7¾ |
| 45 | 63 | 90 | 360 | 315 | 270 | 45 | 12½ | 9 | 8⅝ |
| 52½ | 73½ | 105 | 420 | 367½ | 315 | 52½ | 12½ | 11⅛ | 8 |

For another make of battery the same rates of discharge give the following figures:

| Discharge in Amperes Per Hour During | | | Ampere Hour Capacity When Discharged in | | | Normal Charging Rate | Outside Dimensions of Jar in Inches | | |
|---|---|---|---|---|---|---|---|---|---|
| 8 Hrs. | 6 Hrs. | 3 Hrs | 8 Hrs. | 6 Hrs. | 3 Hrs. | | Height | Length | Width |
| 7½ | 8½ | 15 | 60 | 52½ | 45 | 7½ | 8½ | 6½ | 9 |
| 9⅜ | 13⅛ | 18¾ | 75 | 65⅝ | 56¼ | 9⅜ | 8½ | 6½ | 9 |
| 11¼ | 15¾ | 22½ | 90 | 78¾ | 67½ | 11¼ | 8½ | 6½ | 10½ |
| 10 | 14 | 20 | 80 | 70 | 60 | 10 | 12½ | 7 | 9 |
| 15 | 21 | 30 | 120 | 105 | 90 | 15 | 12½ | 7 | 9 |
| 20 | 28 | 40 | 160 | 140 | 120 | 20 | 12½ | 8⅝ | 9 |
| 25 | 35 | 50 | 200 | 175 | 150 | 25 | 12½ | 10 | 9 |
| 30 | 42 | 60 | 240 | 210 | 180 | 30 | 12½ | 12½ | 9 |
| 35 | 49 | 70 | 280 | 245 | 210 | 35 | 12½ | 12½ | 9 |
| 40 | 56 | 80 | 320 | 280 | 240 | 40 | 15½ | 12⅝ | 9 |
| 50 | 70 | 100 | 400 | 350 | 200 | 50 | 15½ | 12⅝ | 10⅝ |
| 60 | 84 | 120 | 480 | 420 | 360 | 60 | 15½ | 12⅝ | 10⅝ |

The variation in figures between the two types mentioned is largely due to the number of plates per jar and to other points of construction. Apart from any considerations of efficiency, the driver of an electric carriage should carefully bear in mind the figures supplied by the manufacturers of the type of battery he

uses, in order to judge (1) how long the present charge will last; (2) whether he is exceeding the normal rate of discharge, and thus contributing to the unnecessary waste of his battery and incurring other dangers that may involve unnecessary expense. As a general rule the 1-hour discharge rate is four times that of the normal, or 8-hour discharge, and considerations of economy and prudence suggest that it should never be exceeded, if, indeed, it is ever employed. The 3-hour discharge, which is normally twice that of the 8-hour, is usually the highest that is prudent, while the 4-hour discharge is the one most often employed for average high-speed riding. Thus, most makers of automobile

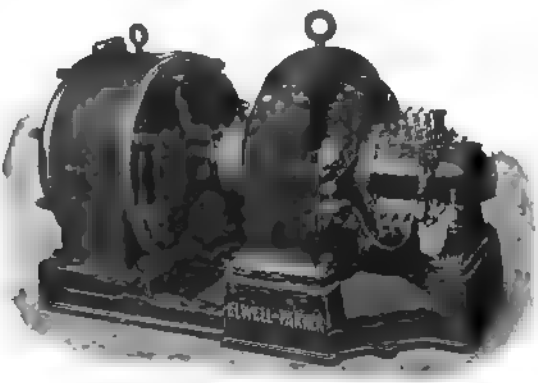



FIG. 319.—Elwell-Parker Motor Generator Set for Charging Vehicle Storage Batteries. This machine has an output capacity of about 15 horse power

batteries give only the 3 and 4-hour discharge rates in specifying the capacity of their products

**High Charging Rates.**—Occasionally it is desirable to charge a battery as quickly as possible, in order to save time, as when belated and far from home with an electric vehicle that has almost reached its limit. As a general, if not an invariable, rule, such a procedure should not be adopted unless the battery is thoroughly discharged, and not then, unless done by a person who thoroughly understands what he is about; battery-makers will always furnish data and directions to meet emergencies.

In charging a battery at a high rate, the danger to be avoided is the tendency of the cells to heat. The troubles that might arise from this cause may be prevented by immediately reducing the current strength. The proper rate of charge for a given battery of cells may be thus discovered by experiment. A battery should never be charged at a high rate unless it be completely exhausted, since it is a fact that the rate of charge that it will absorb is dependent upon the amount of energy already absorbed.

As given by a well-known vehicle manufacturer, the following data on discharging and rapid charging of a given make of battery will be found typical:

| Ampere Hour Capacity Discharged in— | | | | | Normal Charging Rate | Rate in Amperes for a 3-Hour Charge | | | | | Rate in Amperes for a 45-Minute Charge | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 Hr. | 4 Hr. | 5 Hr. | 6 Hr. | 8 Hr. | | ½ Hr. | ½ Hr. | ½ Hr. | ½ Hr. | 1 Hr. | 20 M. | 5 M. | 5 M. | 10 M. | 5 M. |
| 34 | 38 | 40 | 42 | 48 | 6 | 36 | 20 | 16 | 10 | 5 | 72 | 52 | 36 | 16 | 5 |
| 45 | 50 | 53 | 55 | 64 | 8 | 48 | 28 | 20 | 16 | 7 | 96 | 68 | 48 | 20 | 7 |
| 66 | 73 | 78 | 81 | 96 | 12 | 70 | 40 | 30 | 20 | 10 | 140 | 100 | 70 | 30 | 10 |
| 112 | 124 | 132 | 137 | 160 | 20 | 128 | 68 | 52 | 32 | 17 | 238 | 170 | 119 | 51 | 17 |
| 140 | 155 | 165 | 171 | 200 | 25 | 150 | 86 | 62 | 42 | 21 | 300 | 214 | 150 | 64 | 21 |
| 168 | 186 | 198 | 206 | 240 | 30 | 178 | 102 | 76 | 50 | 26 | 356 | 254 | 178 | 76 | 26 |
| 196 | 217 | 231 | 240 | 280 | 35 | 208 | 118 | 90 | 60 | 30 | 420 | 300 | 210 | 90 | 30 |

As here shown, the 96 ampere-hour cell requires, for charging in three hours: For the first half hour, 70 amperes; for the second, 40 amperes; for the third, 30 amperes; for the fourth, 20 amperes, and during the last hour, 10 amperes. It may also be charged at the following rate in 45 minutes: 140 amperes for the first 20 minutes; 100 amperes for the next 5 minutes; 70 amperes for the next 5 minutes; 30 amperes for the next 10 minutes; 10 amperes for the last five minutes. This is the rate to be followed when the battery is completely discharged.

Such figures would undoubtedly vary for different makes of battery, but, when once known should never be departed from, except by an expert who knows perfectly what he is doing in any given case. Such a person, however, would likely be more than usually careful to observe rules. In fact, these rules are imperative, and a current of a given strength should not be continued over the time specified in the directions, nor after the voltmeter records a pressure of 2.6 volts per cell.

**General Points on Care.**—It is unnecessary to give a long series of minute directions on what to do and what not to do in all imaginable conditions. If the user of a storage battery will always remember that this apparatus is a very delicate one; that it will do so much in a given time, and no more; that it must be used and treated quite as carefully as a living thing; that any attempt to make it do more than experts have stated that it can do will only involve failure, disaster and expense—perhaps also danger—he will have mastered the substance of what the best-worded treatise could tell him.

When charging a battery particular care should be taken not to have a naked flame anywhere in its vicinity. This is necessary because during that process inflammable gases, principally hydrogen, are given off, and the result will be more picturesque than enjoyable. To either discharge or charge a battery at too rapid a rate involves the generation of heat. Thus, while this is not liable to result in flame under usual conditions, the battery may take fire, if it is improperly connected or improperly used.

A well-known European authority specifies three reasons for this accident:

(1) Faulty connection of conductors leading to the controller.

(2) The use of such a conductor that is so long as to lie over the battery, so that the insulation is rubbed off, causing a short circuit.

(3) Short circuit caused by acid splashed from the battery eating the insulation of such conductors.

His directions are sensible and practical: (1) Set the controller at rest; (2) open the switch or withdraw the emergency plug; (3) open the battery case and disconnect the battery from the rest of the machinery. This will cause the fire to go out of itself.

In driving an electric vehicle the battery should be saved as much as possible, particularly on steep hills and rough roads. If the amperage rises abnormally on a hill it is better to tack from side to side than to risk mishaps.

If under such conditions, the voltmeter shows a fall below 1.75 per cell, it does not necessarily indicate that the battery is exhausted or injured. However, a careful driver will stop his carriage for a few minutes, when it will be probable that the normal reading will again be shown. If this result follows often in succession, the battery had better be examined by an expert. Generally, however, it is merely the result of hard working.

**Edison Battery: Theory and Construction.**—The recently perfected Edison storage cell, although a departure in several particulars from the general theory of electrical accumulators hitherto recognized, may be classed with those types of battery constructed on the principle of having the plates of opposite polarity constructed of diverse materials. Among such may be mentioned the so-called lead-zinc, lead-copper and alkaline-zincate, in which one plate was formed of zinc, of copper, or other suitable substance. None of them has been used in automobile work.

Following his usual procedure, Mr. Edison started his investigations with the theory that the ideal storage cell should embody the following peculiarities:

(1) An alkaline "electrolyte"—all corrosive acids being eliminated; (2) active materials insoluble in the liquid; (3) a solution that should remain the same under all conditions; (4) immunity from deterioration or disintegration in use; (5) simplicity in the process of charging; (6) immunity from injury by overcharging or overdischarging; (7) a high rate of charge and discharge; (8) small weight per horse power per hour and constant discharge capacity through extended periods.

As the result of investigations with a wide variety of substances, Mr Edison finally constructed a cell with an oxide of iron for the negative element, and a superoxide of nickel for the positive, with a solution containing about twenty per cent. of potassium hydroxide by weight.

Mechanically, also, the construction differs from ordinary accumulators. Each grid, or plate, formed of steel, has twenty-four rectangular openings, giving it somewhat the apearance of a window. Into each of these is fitted and pressed a flat box or pocket—the one part of which engages into the other, like a box and cover, each being thoroughly perforated. The active material is placed in these boxes, the nickel in those of one grid, the iron in those of the other. The construction is thus extremely light and compact.

**The Theory of Operation.**—In operation, the theory involved is simply the transfer of oxygen from one material to the other—from the nickel to the iron in charging, and from the iron to the nickel in discharging. The solution furnishes merely a suitable means of transfer.

**Data on Charging and Discharging.**—The several sizes of cell, as at present manufactured, differ only in the number of

plates and in capacity, the dimensions of the plates being the same in each case. The following table gives the general data relating to the sizes of cell suitable for automobile work:

| Number of Plates. | E-18. | E-27. | E-45. |
|---|---|---|---|
| Capacity in ampere hours | 105 to 115 | 160 to 175 | 260 to 280 |
| Average discharge voltage per cell | 1.23 | 1.23 | 1.23 |
| Rates of discharge in amperes | 30 | 45 | 75 |
| Satisfactory rates of charging in amperes | 40 | 65 | 100 |
| Suitable times of charging in hours | 3¾ | 3¾ | 3¾ |
| Weights in pounds per cell complete, including solution | 13 | 17½ | 28 |

As may be seen, the average discharge voltage is lower than in other types of cell, the available pressure being, in fact, cut down fifty per cent. The advantage realized, however, is in durability, rather than in high capacity. A battery of 32 such cells, rating 160 ampere-hours, will give at a 30-ampere discharge a travel radius of 40 miles at 15 miles per hour for a light runabout. In relation to its weight, however, the Edison cell is very much more powerful than the average of other types. According to the data furnished by Professor Kennelly, the average lead-lead cell yields between 4 and 6 watt-nours per pound weight, which is between 124.5 and 186.5 pounds per horse-power hour at its terminals, or an energy sufficient to raise its own weight through a vertical distance of from 2 to 3 miles (3.2 to 4.8 kilometres) against the force of gravity. The Edison battery, on the other hand, yields 14 watt-hours per pound weight, which is about 53.3 pounds per horse-power hour at its terminals, or an energy sufficient to raise its own weight through a vertical distance of 7 miles (11.26 kilometres).

It also embodies the advantages of being virtually uninjured by overcharge or overdischarge, and of requiring no other ordinary care than the occasional addition of pure water to maintain the proper level of the solution in the jars.

**Battery-Charging Apparatus.**—A storage battery may be charged from direct-current mains having the proper voltage if, as is not always possible, such a circuit is available. Since, however, a current of as great uniformity as possible is required, and existing conditions must be met in each separate case, it is the rule to use a motor-generator set with a regulating switchboard. Such an apparatus consists of a direct-current dynamo, driven direct from the shaft of a motor, which, in turn, is energized by current from the line circuit. With a direct current on the line,

a direct-current motor may be used; but with an alternating current an induction motor is required. The speed of the motor is governed by a rheostat, and the output of the dynamo is thus regulated as desired.

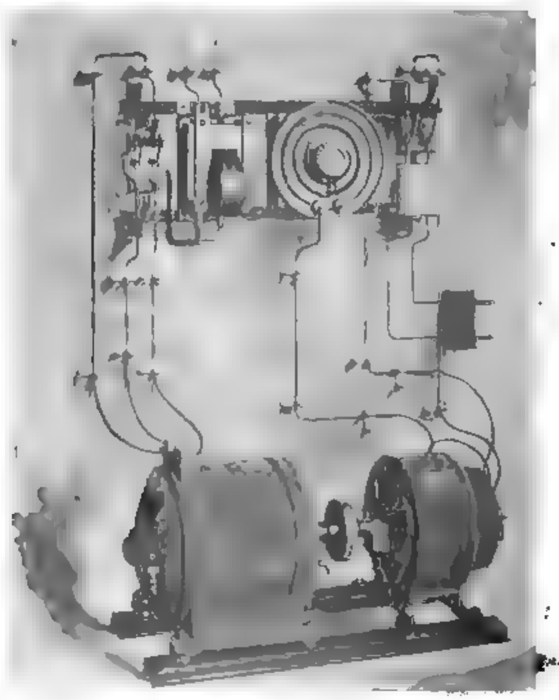
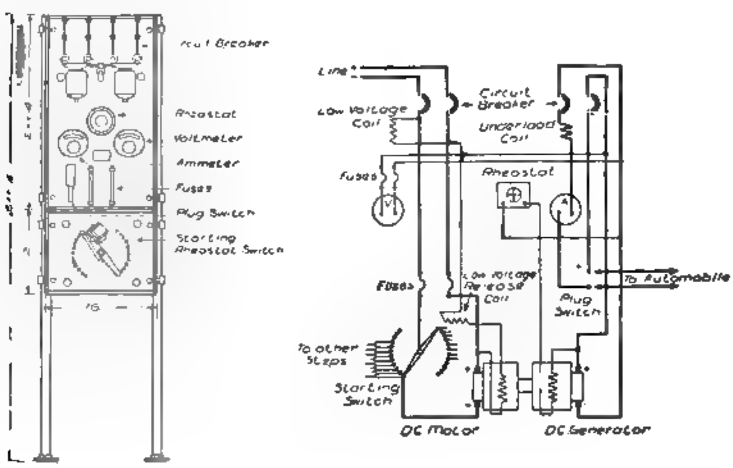


Fig. 290.—Waverley Motor-generator Charging Set for Use on a Single-phase Alternating Current Circuit of 100 to 110 Volts (60 Cycles). This apparatus will give a current of 15 amperes at 65 volts in charging a 21-cell battery, or 10 amperes in charging a 30-cell battery.

A typical outfit of this description is shown in the accompanying diagrams, which show the circuits of a switchboard and charging set, operated from both direct and alternating-current line circuit. The switchboards are equipped with a voltmeter for indicating the pressure of the generator; an ammeter for indicating the amount of current being supplied to the batteries;

an underload coil to automatically shut down the motor-generator set when the battery is fully charged; a low-voltage coil, to open the circuit on the moment of cutting off the power, thus fully protecting the motor, preventing the battery from running the dynamo motorwise and involving that the starting theostat be used whenever the motor is to be used. These operations may be performed manually by the use of circuit-breaking handles.

**Method of Operating.**—An idea of the procedure involved in the use of such an apparatus may be obtained from the following items furnished by the General Electric Company's outfits:




FIGS. 821, 822.—Switchboard and Motor-generator Circuit Connections for Charging a Battery from Direct Current Mains.

(1) Pull down the tripping handle of the circuit breaker and close the two outside poles which connect the motor circuit. The tripping shaft is then automatically locked so that the breaker will not reopen. Then push the core of the low-voltage coil (right-hand coil) up as far as it will go.

(2) Start the motor.

(3) Regulate the generator to give about the desired charging voltage.

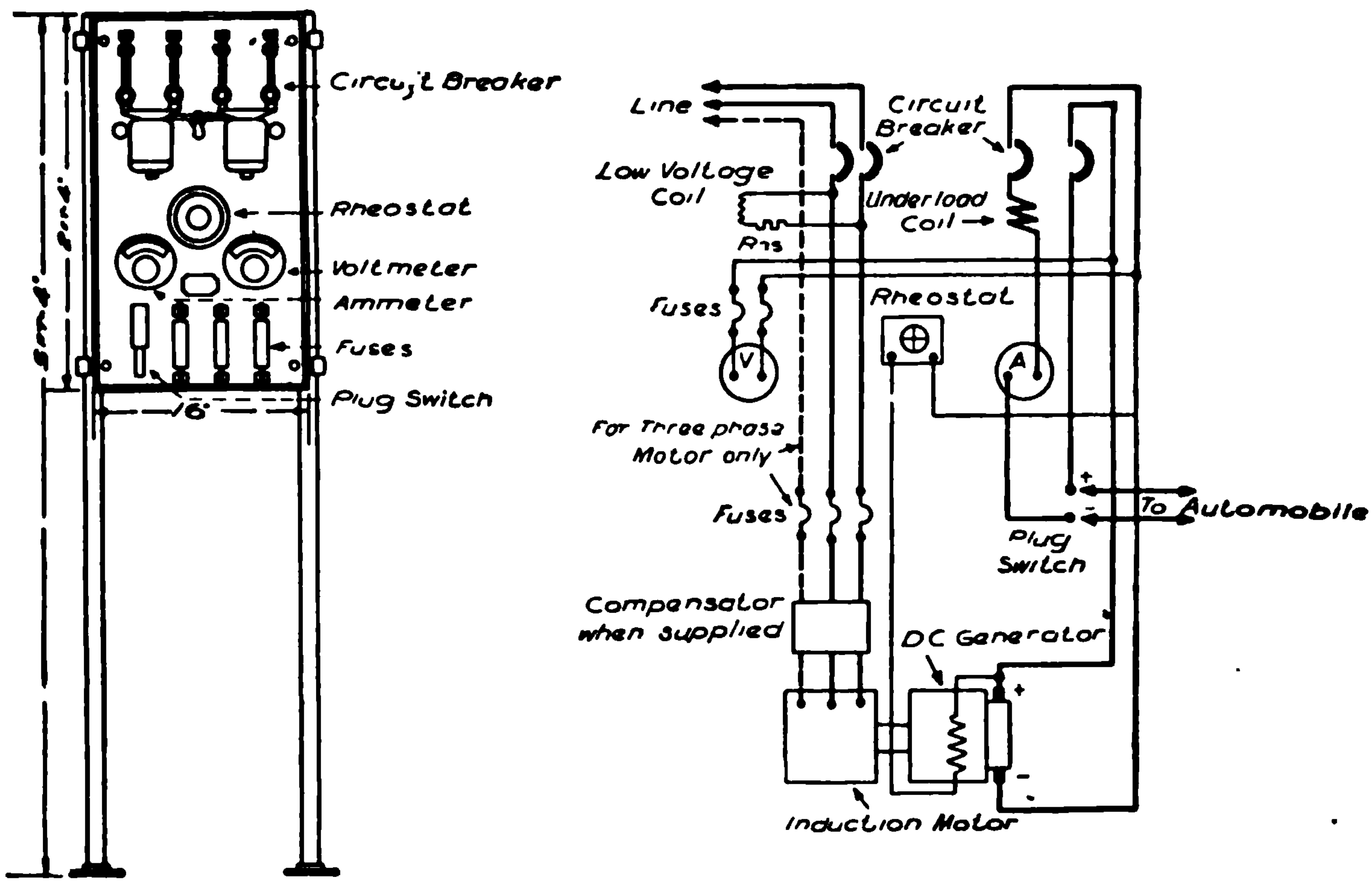
(4) Connect cable to automobile and attach to panel by means of plug switch.

(5) Raise the core of the underload coil (left-hand coil) up as high as it will go, and while holding in this position close the

other two poles of the circuit breaker. The closing of these two poles releases the lock on the tripping shaft so that the breaker will then operate on either underload or low voltage.

(6) Regulate generator voltage until ammeter indicates the normal ampere charging rate of the storage battery.

Dynamos are also furnished with a small gas engine, the speed being regulated by adjusting the intake of fuel, and the pressure and current by a suitable switchboard.




FIGS. 323, 324.—Switchboard and Motor-generator Circuit Connections for Charging a Battery from Alternating Current Mains. The connections of a third wire are shown, for use in case a three-phase circuit is available.

# CHAPTER THIRTY-EIGHT.

## CONSTRUCTION AND OPERATION OF A STEAM ENGINE.

**The Slide Valves of a Steam Cylinder.**—The mechanism by which steam is admitted to the cylinder of a steam engine, consists of a sliding valve of such a shape as to open communication from one end of the cylinder to the exhaust, while the other end of the cylinder is receiving steam direct from the steam chest. This will be readily understood from the accompanying illustration. There are two kinds of valves in common use on steam carriage engines; the common D-valve shown herewith, and the piston valve, as shown in a number of engines hereafter to be described. The object obtained by both valves is the same, although the piston valve is preferred by many engineers because it is better balanced in its operation, and also because, owing

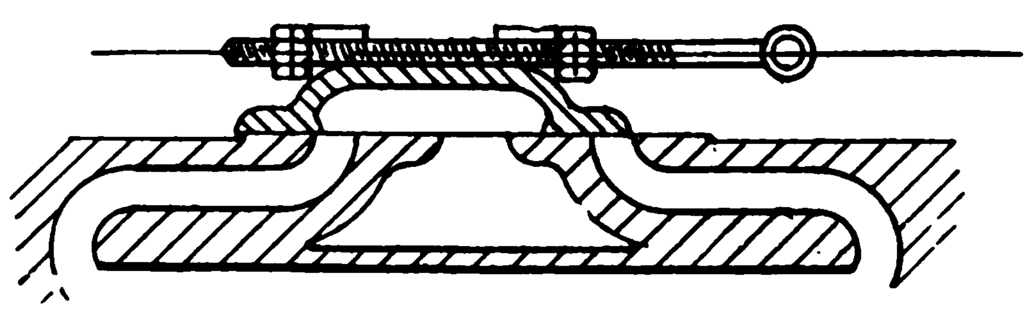


FIG. 325.—Slide Valve of a Steam Engine, showing position after cut-off of steam from right-hand end of cylinder, the exhaust continuing full from the left-hand end.

to its packing rings, it is less liable to leakage. However, with a well-made valve of either variety, the ends of economy and durability are equally maintained.

**The Piston of a Steam Engine.**—The piston of a steam engine, as shown in an accompanying figure, usually consists of a flattened cylindrical piece of slightly smaller diameter than the bore of the cylinder, in which it slides. Steam-tight contact is obtained by springing packing rings into grooves cut in its circumference. The accompanying cut shows three such rings sprung on the piston. The steam admitted through the inlet valve bears upon one face of the piston, and by its expansive energy causes the piston to move. As may be understood,

however, from the fact that the piston rod is attached to one face of the piston, the bearing surface of the steam is decreased as the area of the rod. This item must be considered in exact calculations on engine horse-power, although for ordinary purposes it is negligible.

**The Operation of the Slide Valve.**—The valve controlling the inlet and exhaust ports of a steam cylinder is made of such length that, when in mid-position, it completely closes both inlet ports, neither admitting steam nor allowing it to be exhausted. In the valve shown on the accompanying sectional cut, it is evident that, supposing it to be moved either to the right or to the left, the communication will be opened with the exhaust port on the one side, sooner than with the steam chest on the other, thus permitting with a very slight

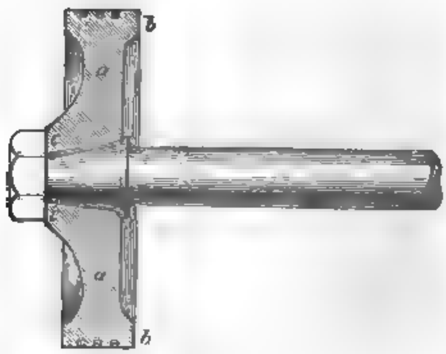



FIG. 326.—The Piston of a small double-acting steam engine, showing method of connecting the piston rod, and the position of the packing rings. The parts are: *a*, *a*, the body of the piston, *b*, *b*, the circumference bearing the packing rings; *c*, *c*, the central boss receiving the coned end of the rod

variation in the length of the stroke, that the exhaust remain open even while the inlet of the steam to the opposite face of the piston is cut off. In calculating the operation of cylinder valves there are two important items to be considered—the "lap" and the "lead" of the valves. The "lead" of a valve is the amount by which the steam port is open when the piston is at the beginning of the stroke. According as this is more or less the inlet of steam is varied through the several fractions of the stroke. The lead may be changed either by cutting down the lap of the valve, or by varying the stroke length of the valve and its rod.

The "lap" of a valve indicates any portion added to the length of the valve, so as to increase the portion of the stroke during which the ports are covered, beyond that length which is positively required to insure the closing of all ports when the valve is in mid-position. There are two kinds of "lap." The "outside lap" is any portion added to the length of the valve beyond that necessary to cover both inlet ports at mid-position. The "inside lap" is any portion added to the hollow or inside portion of the D-valve, over and above what is necessary in order to cover the inner edges of the steam ports, and to close the exhaust port from both sides when the valve is in mid-position.

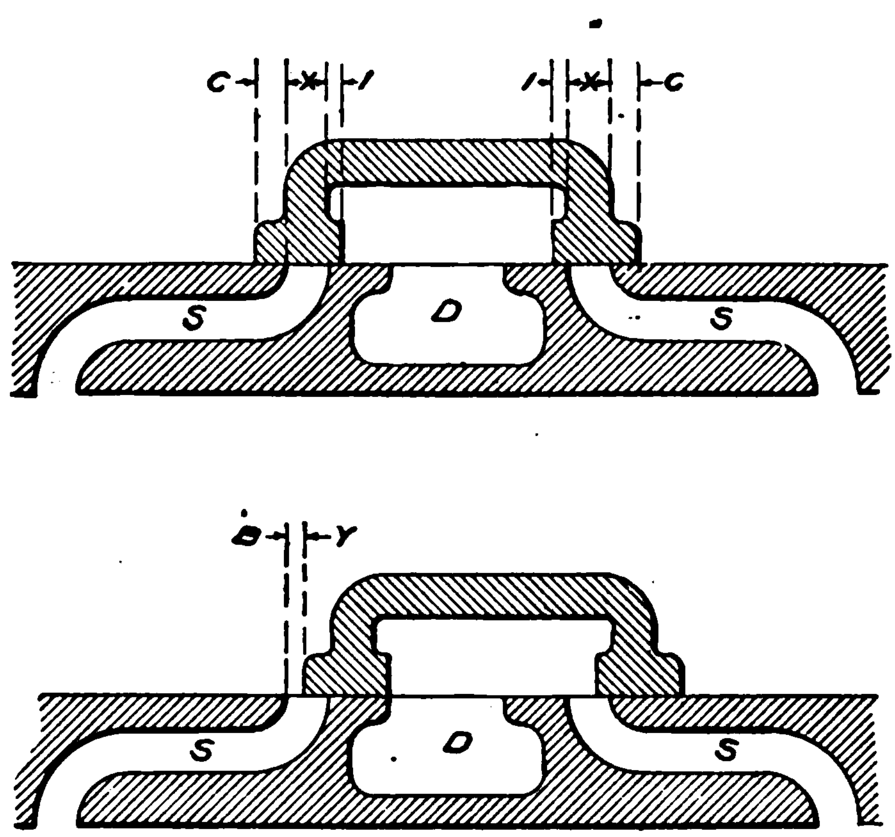



**Fig 327.—Diagrams illustrating the "Lap" and "Lead" of a Steam Cylinder Slide Valve.** In both sections, S and S are the steam ports, and D the exhaust. The upper section illustrates the "laps" of a valve; the space between the lines C and X giving the "outside lap," and between the lines X and I the "inside lap." The lower section illustrates the "lead" of a valve; the space between lines B and Y showing the opening of the valve at the beginning of the right-hand stroke.

As already suggested in the previous chapter, the exhaust valve is closed somewhat before the completion of the stroke, thus allowing the residual steam in the clearance to be compressed somewhat before the opening of the inlet. The most important result obtained in this manner is that the compression produces a temperature, as near as possible, the same as that of the incoming steam, which is an efficient factor in heat economy, although producing some back pressure that slightly reduces the M. E. P. Another important consideration is that a soft cushion is thus provided for the forward-moving piston

which acts to save unnecessary wear on the crank and other moving parts, as is most essential in a small engine.

From the operations of this valve and cylinder, it must be evident that its stroke cannot be equal to that of the piston in the main cylinder. It cannot, therefore, be operated direct from the crank-shaft of the engine. Accordingly, the most usual method of operating the steam valves of an engine is by an eccentric on the main shaft, which operates the valve rod. This device may be either a single or double eccentric, according to the requirements, but when ready reversal of the engine's motion is desired, as in the case of a locomotive or marine engine, the double eccentric with the shifting, or Stephenson, link is most generally used.

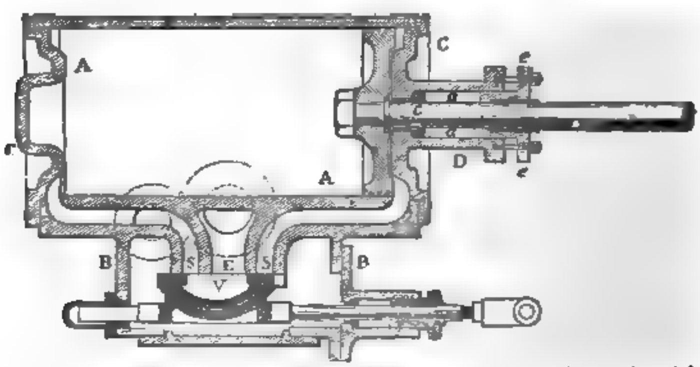



FIG. 328.—Section through a Steam Cylinder and Valve Chest, showing parts. A is the cylinder. B, the steam chest: C and C, the cylinder heads: D, the stuffing box; a and a, the packing gland; c, the piston rod. E, the exhaust port: S and S, the steam ports; V, the slide valve; e, e, the packing gland, held in place by screws in this engine.

**The Eccentric Gear and Link Motion.**—An eccentric is a circular piece of metal, a wheel in fact, except for the fact that instead of turning upon its centre, it is attached to the shaft at a point near its periphery. Around this disc-shaped piece is attached a circular metal strap, joined to a rod, which may be either attached direct to the valve rod, or, where two eccentrics are used, to one end of the swinging link. The link is an arc-shaped metal piece, usually made with a slot through the greater part of its length It is hung from its centre point to a link-saddle, which, as shown in the accompanying figure, is bolted to either side of the slot and is suspended from the link-hanger

either above or below. Within the slot is set a link-block, as it is called, so that it may slide in the slot through its entire length, whenever the link is raised or lowered on its hanger. To this link-block is attached the valve rod. The general arrangements of the link motion may be understood from the accompanying illustration.

**The Operation of the Shifting Link.**—As already stated, the link motion was originally intended only for reversing the engine, which is to say to enable the steam to be cut off from

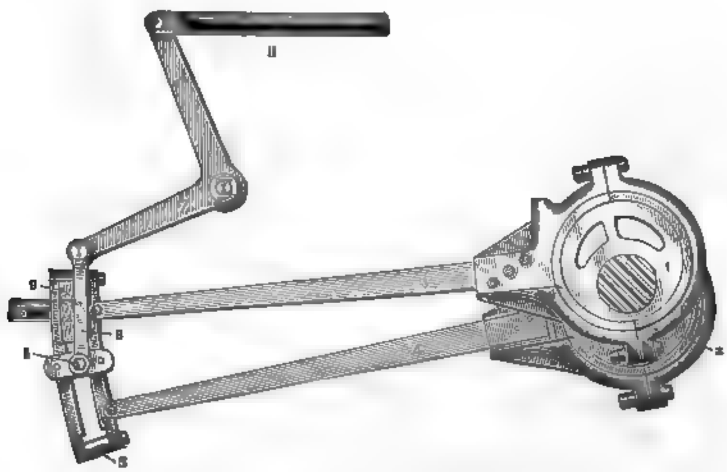


FIG. 329.—Diagram of the Link Motion and Eccentric Gear of a Steam Engine. The parts shown are (1) backward eccentric; (2) forward eccentric; (3–4) eccentric rods; (5) slotted shifting link; (6) link hanger, (7) reversing arm; (8) link saddle pin; (9) link block; (10) valve stem; (11) reach rod The position shown in the cut indicates that the backward eccentric is in gear which gives a reverse motion to the engine.

one side of the cylinder and admitted to the other, whenever desired, by shifting the motion of the slide-valve. In addition to this function, however, the link motion provides a means for using the steam expansively, when cutting off the supply of live steam at any earlier point in the piston stroke, which act is accomplished by reducing the travel of the slide-valve. When the link-block is at one end of the slot, the valve receives the motion of the eccentric rod attached to that end of the link, and, consequently, since the links are set at angles somewhat greater than 180 degrees, the one is for the forward motion of the en-

gine, the other for the reversed motion. In the accompanying illustration, the backward eccentric is in gear. By this means, whenever the link is shifted, only the eccentric whose rod stands opposite the link-block imparts its motion to the valve. The other is practically inactive, except for imparting a slight oscillatory motion to the link, which in general practice is negligible. The link which is in gear acts, in reality, like a short-throw crank, or as if it were a single eccentric. From the position of "full-gear"—that is, when the link-block stands at either end of the slot—the travel of the valve may be more or less modified until the centre point of the slot is reached, which point is called

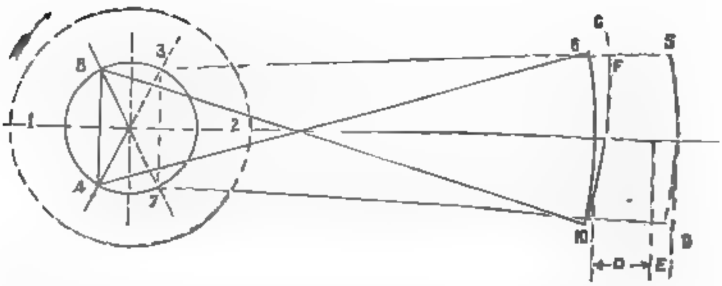



**Fig. 330.—Diagram of the Operation of the Link Motion.** The centres of the two eccentrics being at 4 and 8, the crank pin at 2, the link at mid-gear, the eccentric rods will be indicated by the full lines, 4-6, 8-10. When the crank pin is at 1, the centres of the eccentrics will be at 3 and 7, and the positions of the rods on the dotted lines, 3-5 and 7-9. The distance, D, indicates the vertical distance between the centres of the eccentrics in the full and dotted-line positions. If from the centre, 8, with the rod as the radius, an arc be drawn to F, the distance, C, shows the position of the link if both rods were "open" with the crank at the cylinder end, 2, instead of at the opposite dead centre, 1. The distance, C, is equal to the distance, E, and the total distance (D + E) that the valve moves is twice the lap, plus twice the lead, plus the distance, or angularity, occasioned by the rods being crossed, when the crank is on the cylinder end dead centre, 2, becoming opened when the crank is at dead centre, 1.

mid-gear. There the travel in either direction is so slight that the steam and exhaust ports of the cylinder are not opened. This is in reality the "dead point," and further shifting of the link in the same direction begins the process of reversing by increasing the travel of the valve in the opposite direction. When at mid-gear the valve partakes of the motion of both eccentrics equally, but since their motion describes a cassinian, or flattened figure 8, laid on its side, of which the link-block is the centre, the motion is at its point. Although this general movement is continued so long as the engine is in operation, it is reduced to practical zero at the link-block set at full gear.

When the link is at full gear, the travel of the valve is equal to twice the throw of the eccentric, less the angularity of the eccentric rod. When the link is at mid-gear, the travel of the valve is equal to twice the lap and lead of the valve, plus twice the angularity of the eccentric rods. By the angularity of the

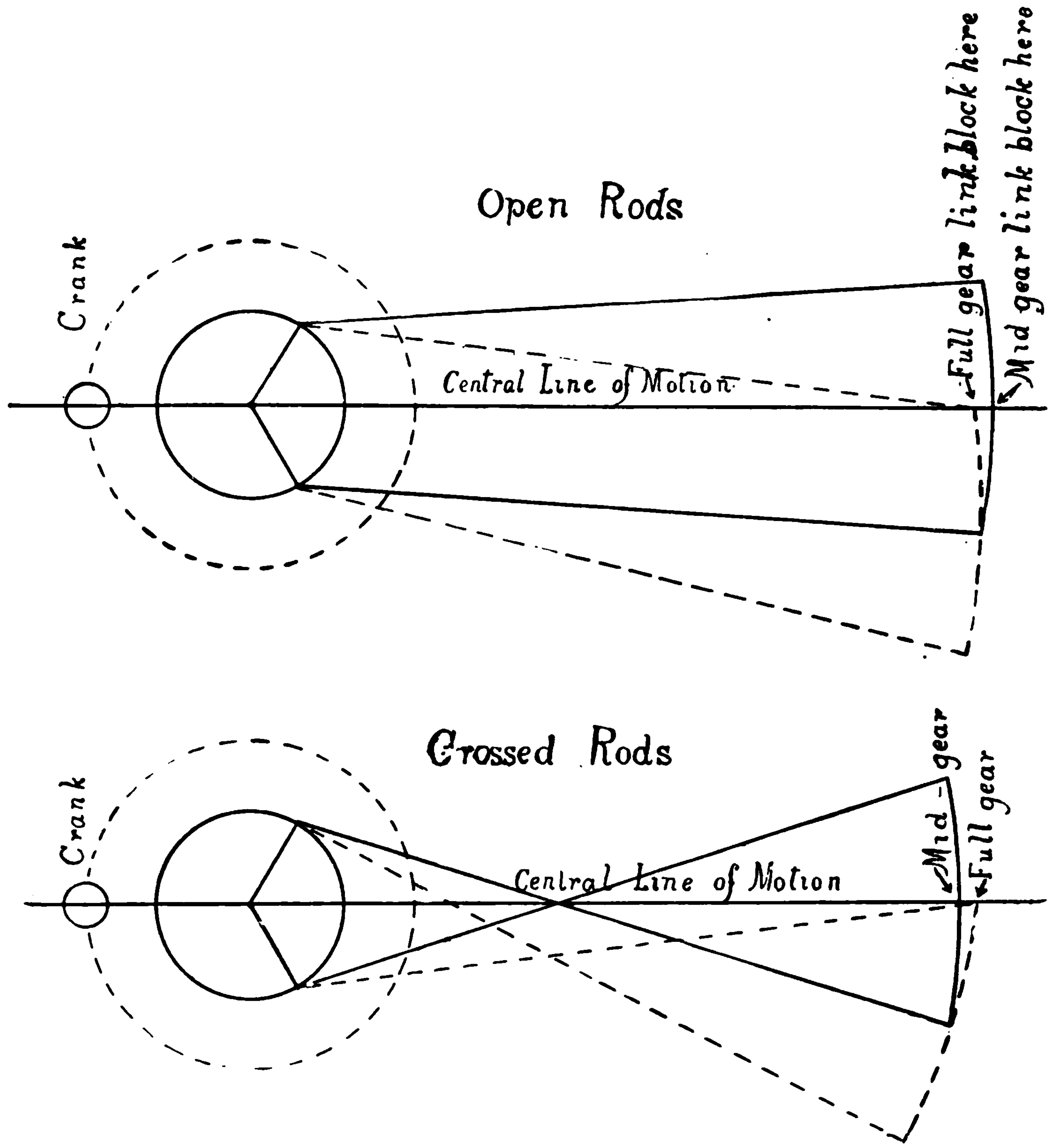



FIG. 331.—Diagram showing the positions of the eccentric throws and rods at full gear and mid-gear, when the rods are "open" and "crossed" with the crank at the forward dead centre, marked 1 in the previous cut.

eccentric rods is meant the distance the centre of the link or the valve would move, should the rod of the geared eccentric be disconnected from it and connected with the other link. The amount of the angularity thus, of course, varies with the length of the rods. The shorter the rods, the greater the travel of the

valve, owing to the crossing of the rods during a one-half revolution of the crank. When the eccentric rods of a direct connected link motion are disposed as shown in the accompanying diagram, and the link motion and gear of the crank is at the dead point marked 1, the rods are said to be open. If they are disposed as shown by the dotted lines in the same figure, and the crank is at the dead point, 2, they are said to be crossed. There is, however, an important difference in the operation involved in the relative positions of the rods to the crank, as shown by the travel of the steam valve, since rods which are open at the specified point give an increasing lead from full-gear towards mid-gear, while rods crossed at that point give a decreasing lead in the same direction. Variation of lead from full-gear

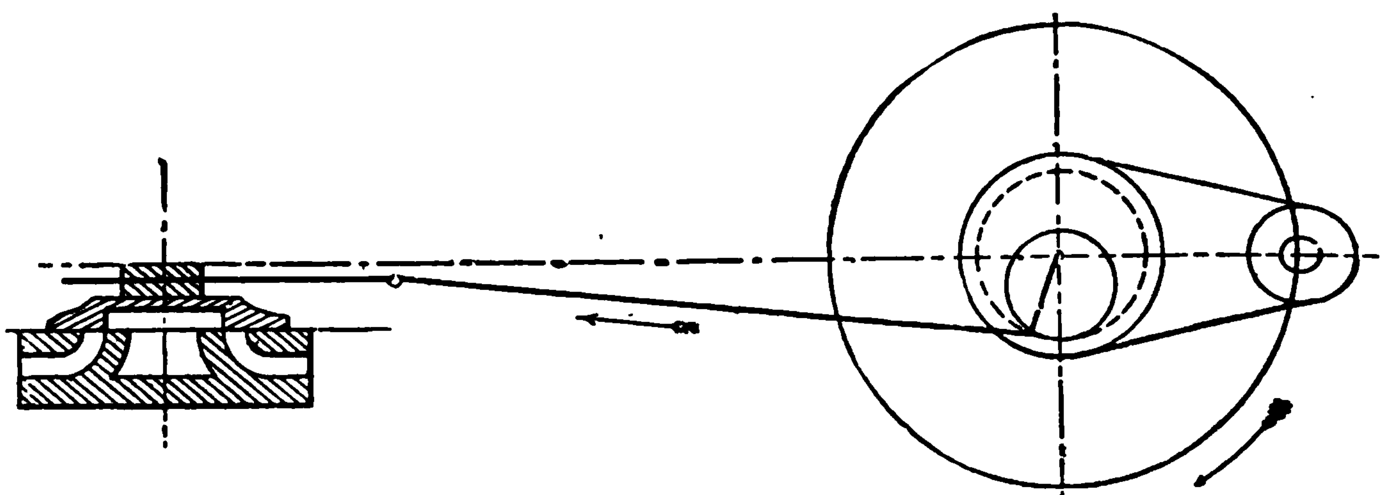


FIG. 332.—Diagram with a single eccentric, illustrating the position of the steam valve, when the crank pin is at the forward dead centre, the throw of the eccentric being at an angle off the perpendicular. The arrows show the direction of motion.

to mid-gear is due to the curvature of the link-arc, and for a link of short radius is more pronounced than for a link of longer radius. As a general rule, the radius of the link is equal to the length of the eccentric rod.

**The Practical Expansion Ratio for Steam.**—In the practical operation of the steam engine, as most generally understood, the steam is fed direct from the boiler to the cylinder, there expanding from its original pressure to a number of volumes, proportioned to the length of the stroke and point of cut-off. The idea of cutting off the supply of steam before the completion of the stroke, and making use of its expansive energy during the remaining portion, constitutes, as we have seen, the first improvement made by Watt. According to Boyle's Law, already quoted, the pressure of the steam is in exactly inverse ratio to

its expansion, which is to say that when a body of steam is expanded to twice its original volume, it should have just one-half its original pressure, so long as the temperature be constant. This law is never exactly followed in practice, the general rule, as shown by indicator diagrams, being a rapid fall during the first period of expansion and a more gradual one in the latter

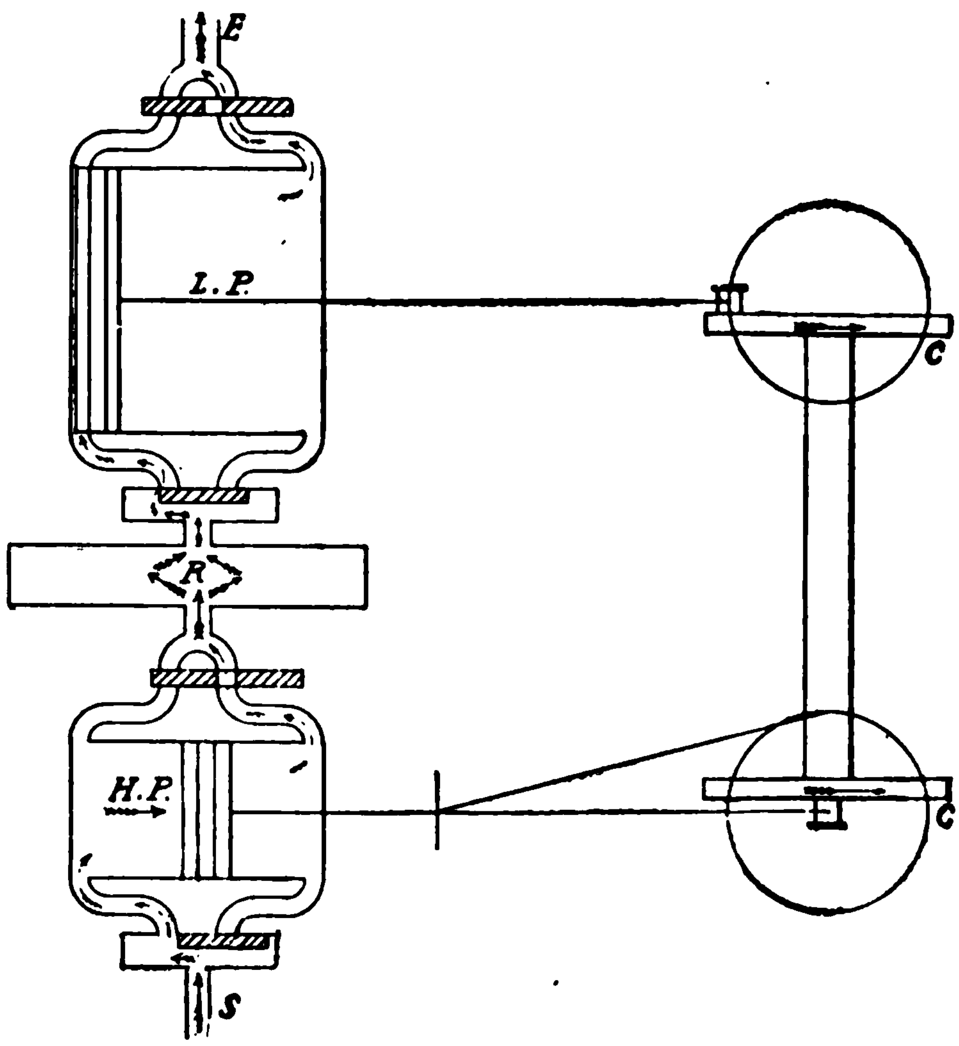



FIG. 333.—Diagram of a "Cross Compound" Steam Engine. The cranks, C and C, are at 90°. The high-pressure steam port is at S; the H. P. exhaust to L. P. cylinder at R, and the exhaust to atmosphere from the low-pressure cylinder, at E.

period. However, for general purposes, the law is assumed to be perfectly operative, and the rule for calculating the pressure at any point of expansion, is to divide the original absolute pressure by the number of times it has expanded. Thus, steam fed to a cylinder at 100 pounds gauge, or 115 pounds absolute, has a pressure of 57½ pounds when expanded to two volumes, a pressure of 38 1-3 pounds when expanded to three volumes and a pressure of 28¾ pounds when expanded to four volumes. It would, therefore, require as many expansions to reduce the gauge pressure of 100 pounds to atmosphere, as 15 is contained in 115, which is 7 2-3 times. If the flow of steam to the cylinder be cut off at one-half stroke, it has been ascertained by numerous experiments, that its efficiency will be increased 1 1-7

times what it would have been if the steam at the same point has been released into atmosphere. The following table gives the efficiency of steam cut off at various other points of the stroke:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Cutting | off at | $\frac{1}{10}$ | stroke | increases | efficiency | 3.3 | times. |
| " | " | $\frac{1}{8}$ | " | " | " | 3.0 | " |
| " | " | $\frac{2}{10}$ | " | " | " | 2.6 | " |
| " | " | $\frac{1}{4}$ | " | " | " | 2.39 | " |
| " | " | $\frac{3}{10}$ | " | " | " | 2.2 | " |
| " | " | $\frac{3}{8}$ | " | " | " | 1.98 | " |
| " | " | $\frac{4}{10}$ | " | " | " | 1.82 | " |
| " | " | $\frac{1}{2}$ | " | " | " | 1.69 | " |
| " | " | $\frac{6}{10}$ | " | " | " | 1.50 | " |
| " | " | $\frac{5}{8}$ | " | " | " | 1.47 | " |
| " | " | $\frac{7}{10}$ | " | " | " | 1.35 | " |
| " | " | $\frac{3}{4}$ | " | " | " | 1.28 | " |

These figures give a general idea of the economy gained by the practice of cutting off the steam at various points of the stroke, but, as is evident, the end of economy is obtained by altering the final pressure in the cylinder, and, consequently, also the mean effective pressure throughout the entire cycle. If, therefore, we wish to utilize the full power of any given boiler pressure, the end of combined economy and high efficiency is far better attained by the operation known as compounding.

**Limits of Varying the Valve Motion by the Link.**—On the question of the practical limits of varying the cut-off of the valve, by varying the motion on the link, authorities seem to vary in regard to the steam engines used on carriages. Several manufacturers, however, use a notched quadrant for enabling the driver to shift the link, as desired, and with apparently good results, in spite of the oft-repeated claim that the engine of a steam carriage is too small to allow of a very wide variation in this respect. On the authority of one or two practical steam-carriage drivers, whose opinions have appeared in print, it may be stated that some advantage in point of steam economy has been achieved by varying the cut-off from, say, seven-eighths to one-half stroke on a level roadway. The majority opinion has it, however, that, although some saving may be achieved in this direction, proper care and management of the motor and parts attain the end far more effectively: since the strain on the driving mechanism incident to shifting the link

increases wear and tear in an even greater proportion tl the gain in steam saving. In short, the situation seems to that a small steam motor requires a fly wheel to compensate f the jar resulting from frequent shifting of the steam inlet.

**On Compounding a Steam Engine.**—A compound engine is one in which the steam is used several times over in as many separate cylinders, although usually applied to engines operating with two cylinders. The steam is fed from the boiler direct to the first cylinder, in which it is cut off late in stroke, in order that its pressure may be utilized to the greatest possible extent The exhaust from this cylinder is then fed into the second cylinder, generally two or three times the cubic contents of the first, and is worked expansively to a point as near atmospheric pressure as possible. The most practical and efficient application of this principle is in the triple and quadruple expansion engines, so largely used in marine work, which, in connection with the vacuum-producing condenser, allows the steam to be worked from the highest available pressure down to practical zero. There are two common forms of compound engines of two or three cylinders, which from the arrangements of the working parts, are known as "tandem-compound" and cross-compound." In the tandem-compound engine, the cylinders are placed end to end, the several pistons operating one piston rod. In the cross-compound engine the cylinders are placed side by side, the two or more piston rods operating on a single crank-shaft. The latter model is that most frequently used in compounding steam engines for motor vehicles.

## CHAPTER THIRTY-NINE.

### SMALL SHELL AND FLUE BOILERS FOR STEAM CARRIAGES.

**Small Shell Boilers for Carriages.**—Many of the best known makes of American steam carriage have vertical fire-tube shell boilers, usually placed beneath the seat. All such boilers are of small dimensions, frequently little over one foot in either diameter or height, with a consequently small water capacity. But they have a very extensive heating surface, owing to the insertion of a large number of fire flues, and, according to many showings, seem capable of generating a power pressure far in excess of the usual rule of proportions for surface. The shells of such small boilers are usually of steel, sheet-riveted or cold drawn piping, with a thickness ranging between three-sixteenths inch (as given for the Marlboro and Victor steam carriages) and five-sixteenths inch (as given for the Foster steam wagon). Such boilers admit a working pressure of between 150 and 180 pounds to the square inch, with blow-off pressure between 225 and 320 pounds, several of them claiming to have withstood tests of more than three times their blow-off pressure. The flues of such small boilers, which are generally of copper, about one-half inch in diameter and 16 B. W. G., or .065 inch thick, are expanded into the tube plates at either end, the joints being secured as strongly as possible.

**Heating Surface of Small Boilers.**—The immense heating surface afforded by using a large number of such flues in a boiler of moderate dimensions may be illustrated by the following figures:

In the ordinary two and four-seat carriages made by the Locomobile Company of America a boiler is used whose dimensions are 14 x 14 inches, with 298 half-inch copper tubes.

Computing for the area of a circle of 14-inch diameter we find it to represent 153.94 square inches, which gives 307.88 square inches as the surface of both tube plates.

Computing for the cylindrical surface of the shell, we find the

circumference to be the product of 14 (diameter) and 3.14159 (ratio between circumference and diameter of a circle), giving 43.9822 inches as the circumferential measure, which, multiplied by 14 (length of shell), gives 615.7506 square inches, or a total surface for the boiler shell of 923.63 square inches, or 6.39 square feet.

With the flue-tubes we may calculate in similar fashion. Thus the inside diameter of each tube is approximately one-half inch, exactly .437 inch. To find the inside circumference, we multiply .437 by 3.14159, which gives us, in full, 1.37287483. Multiplying this by 14, to find the area of each tube, we have 19.22024762

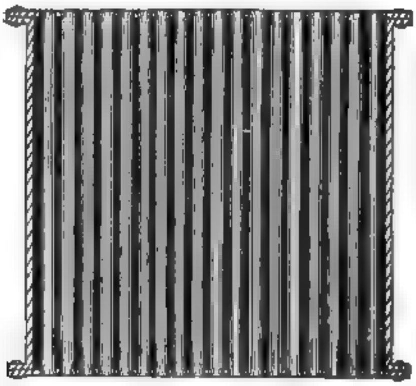


FIG. 331.—Copper Shell and Flue Boiler, with flange connections for the tube plates, as used on the "Locomobile" and other American steam carriages. The shell is strengthened by winding several layers of steel piano wire around the length of the boiler. This cut gives a section on the centre, showing one row of flues.

square inches, which multiplied by 298 (total number of tubes) gives us 5728.633 square inches, or 39.782 square feet, as the heating surface represented by the flues, over six and one-half times the total outside surface of the boiler shell. If to this figure we add 307.88 square inches, or 2.13 square feet, the surface area of the two tube plates, we have 41.91 square feet, as the total heating surface of the boiler.

According to the rule given above, a boiler of such dimensions should be able to drive an engine of about three-horse power. But it has been claimed that this make of boiler has developed over four-horse power, which fact is probably due to rapid steam

generation under fire from a powerful burner, and also the efficiency of the engine used. Similarly excellent results have been achieved with other makes of fire flue vehicle boilers, a fact which amply justifies the course followed by most American carriage builders, of adopting a steam generator of familiar pattern and increasing its efficiency along concurrent lines, instead of spending time and energy in the effort to produce an instrument, which should embody the requirements of perfection.

FIG. 335.—Small Carriage Boiler made from a seamless steel pressing, the lower tube plate being flanged over and riveted in, as indicated at the base of the figure, this being the only seam in the structure.

**The Flues of Small Boilers.**—Several carriage builders still cling to the practice of using steel tubes in their boilers, thinking by this means to supply an additional assurance against explosion. The custom is growing, however, of using cold drawn copper tubes for this purpose, and experience seems to warrant the statement that boilers containing them are quite as durable as those constructed of steel throughout. Copper is superior to steel in boiler construction from the fact that it has a much higher thermal conductivity, involving considerably smaller loss of heat in proportion to its exposed surface; also from the fact that it

more easily resists the chemical action of impure water, in point of preventing both corrosion and the deposit of incrustations, and is less liable to oxidation from the action of heat. On the other hand, it is inferior to steel in the fact that its tensile strength is greatly reduced under increasing temperatures. As quoted by several boiler authorities, its diminution of strength increases from .0926 as compared to steel at 270 degrees, Fahrenheit, to .2133 at 460 degrees, .2558 at 532 degrees and .3425 at 660 degrees. Well-made copper tubes, however, can readily withstand

FIG 336.—Bottom View of a Type of Boiler shown in Fig. 335. exhibiting the method of riveting in the lower tube plate.

a constant working pressure of between 150 and 180 pounds to the square inch, which figures represent the average used in small vehicle boilers. These advantages in copper, both pure and in alloy, led long since to the use of brass tubes in some locomotive and other large boilers, with the best results. For this purpose brass proved far superior to iron, or steel, in resisting the abrading action of small particles of coke or coal drawn through the draught; in having a greater power of springing under increased expansion, and of being less liable to break. On the other hand, if we may deduce a principle from practical

experience on this point, the inferior strength of copper tubes for boilers is a positive advantage, for, since they are more liable to collapse under stress of over-heat and expansion, the effect may be similar to that found in water-tube boilers under similar conditions—the bursting of one or two tubes instead of a disastrous rending of the outer shell. This seems to be the experience in some cases. A prominent steam carriage concern says of its tubular boiler: "If the boiler should accidentally be allowed to run dry and become overheated, all that has ever been known to

FIG. 337.—Another type of Small Carriage Boiler, showing both tube plates inflanged and riveted to a seamless steel tube.

happen is that the tubes collapsed at the ends and the boiler leaked. The water and steam escaping gradually reduce the pressure until none is left—the result of which is that the tubes (a number of them) are ruined and must be replaced."

On the matter of metal and metal combinations suitable for use in boilers, the following is quoted from an excellent article on the subject:

"The question of the strength of materials for boilers was elaborately tested some years ago by the Franklin Institute. It was then found that the tenacity of boiler plate increased with the temperature up to 550 deg. Fahr., at about which point the tenacity began to diminish as the temperature rose. At 32 deg. Fahr. the cohesive force of a square inch section was 56,000 lbs.; at 570 deg. it was 66,500 lbs.; at 720 deg. it was 55,000 lbs.; at 1,050 deg. 32,000 lbs.; at 1,240 deg. 22,000, and at 1,317 deg. 9,000 lbs. Copper follows a different law and appears to be diminished in strength for any increase in temperature. At 32 deg. Fahr. the cohesion of copper was found to be 32,800 lbs. per square inch section, and exceeds this cohesive force at any higher temperature, the indications being that the square of the diminishing strength keeps pace with the cube of the increased temperature. Strips of iron cut in the direction of fiber were found to be 6 per cent. stronger than when cut across the grain. Welding was found to increase the tenacity of the iron, but welding together different kinds of iron was not found to be favorable. Overheating was found to reduce the ultimate strength of plates from 65,000 to 45,000 lbs. per given section, and riveting of plates was found to diminish the strength one-third."

# CHAPTER FORTY.

## OF WATER-TUBE BOILERS, AND THEIR USE IN STEAM CARRIAGES.

**Of Tubular Boilers in General.**—The wide use of tubular boilers in steam carriages and for other purposes is explained by the fact that in its use the problem of how best to control the circulation, to the ends of quick steaming and higher durability, through more uniform distribution of heat, has been best solved. Although very many varieties of tubular boiler possess high efficiency as generators of steam, none of them attain such great power for absorbing heat but what there is still room for efforts to discover some means of neutralizing waste in this particular.

**Advantages of Controlling Circulation.**—Furthermore, by suitable arrangements for directing the rising and falling currents, so that interference is obviated, another very desirable end is attained—chemical impurities, held in solution by the water, and precipitated so as to form scale deposits, when it is evaporated, are prevented from locating and hardening; being received into mud drums suitably arranged at the lowest point of the water chamber, where they can be conveniently removed. According to statistics furnished by various authorities these scale deposits, consisting mostly of lime and other non-conducting substances, interfere with the heat-conducting properties of the metal to an enormous extent: A deposit of 1-16 inch involving a loss of 13 per cent. of the fuel; a deposit of ⅛ inch, a loss of 25 per cent.; a deposit of ¼ inch, a loss of 38 per cent.; a deposit of ½ inch, a loss of 60 per cent. The result of allowing such incrustations to increase will be inevitably that the metal surface exposed to the fire is burned out and the boiler ruined.

**Advantages of Water-Tube Boilers.**—With the water-tube boiler, on the other hand, the fact that the full force of the steam pressure cannot bear on any one extended surface involves that in the event of overheating or sinking of the water level, only one

or two of the tubes will burst with no very serious consequences. Wellington P. Kidder, a boiler expert, enumerates the following ten points of structural advantage in a well-made water-tube boiler, adapted for road wagons:

(1) The water should not be expelled by heat from the tubes nearest the fire; (2) foaming and priming are no more likely than in shell boilers; (3) there need be no joints near the fire; (4) there may be but few parts, easily and cheaply assembled; (5) the weight is about two-thirds that of a shell boiler of equal ca-

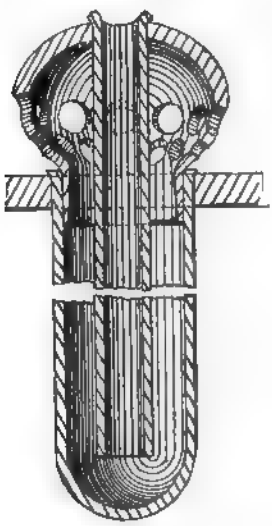


FIG. 338.

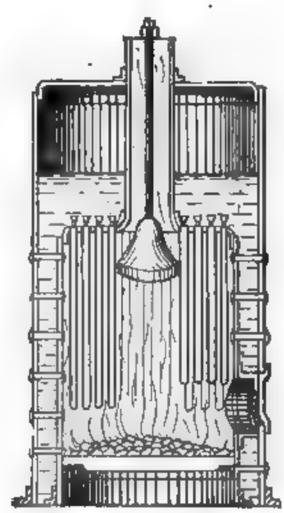


FIG. 339.

FIGS. 338. 339.—Field Water-tube Boiler and one of the Field Tubes, showing inner tube and method of controlling circulation. A number of such tubes are hung over the fire-box of the boiler, as shown.

pacity; (6) being in sections, it may be easily taken apart for cleaning or repairs; (7) an easily removable casing will deflect downward any escape of steam or water, due to breakage of tubes; (8) a natural and rapid circulation through all tubes insured; (9) ample provision for insuring dry steam for the cylinders; (10) the ready possibility of blowing steam through the tubes for removing incrustations, also, between them, for removing soot. In a compliance with such conditions in construction

he finds the following eight points of superiority: (1) All danger minimized; (2) steam quickly generated; (3) weight minimized; (4) superior absorption of heat by inclined tubes; (5) more heating surface found on exterior of tubes; (6) less opportunity for dust accumulation; (7) higher working pressure of steam practicable; (8) better elastic provision for expansion. He confesses, however, that most of the really practical water-tube boilers for vehicles present some one or all of the following three disadvantages: (1) Too much bulk and complication; (2) liability to foaming and priming; (3) danger of expulsion of water from the tubes nearest the fire by overheating. The last-named fault, if not the others also, is to a large extent offset in the De Dion, Weidnecht and Clarkson-Capel water-tube generators by the lower chamber or water-jacket; and in the Lifu generator by the trunk tube and water arch features. The Lifu generator is nearly the most elaborate attempt yet made to mechanically control the water circulation. In the ideal water-tube boiler, however, the tubes would run across the draught through a portion of their length, at least, thus making possible a greater absorption of heat, through the breaking of the air currents. This result is immensely increased when the successive rows of tubes are staggered, so as to still further divide up the draught currents.

**The Field Finger-Tube Boiler.**—A type of water-tube boiler, which has given good service in several steam carriages, notably the Thomson-Ransome coach, built about 1870, and the Velee coach, built about 1880, is of the ordinary fire-engine upright pattern, with a central smoke flue controlled by the form of baffle damper, for regulating the heat currents, shown in the accompanying figure. Instead of five tubes or coils, it has the bottom crown plate fitted with a number of suspended "finger tubes," through which, on account of the peculiar shape of the movable baffle damper, the heated gases are forced to circulate. Each of these tubes, which is closed and rounded off at the bottom end, like a chemist's test tube, is inserted and expanded in an aperture in the crown sheet. In this inner open end, as shown, is inserted a second smaller tube, which, in turn, depends from a perforated globe, or a suitable collar, the three elements being firmly attached. In the style of Field tube shown in the figure, the perforated globe carries a tapering ferrule that is driven into

the end of the outwardly hanging finger tube, thus further securing the joint.

The operation is to be understood readily: The water in the lowest level of the finger tubes is directly affected by the heat of the furnace, and rises along the sides; the descending strata, working down to take the place left by the rising mass, moves through the orifice at the top of the globe and down the central tube. The circulation is thus perfectly guided and, all interference of the rising and falling currents being prevented, the greatest possible percentage of heat is utilized. In spite of the high efficiency of Field tube boilers, they have been almost entirely supplanted in the domain of motor vehicles by other types less difficult to construct and maintain.

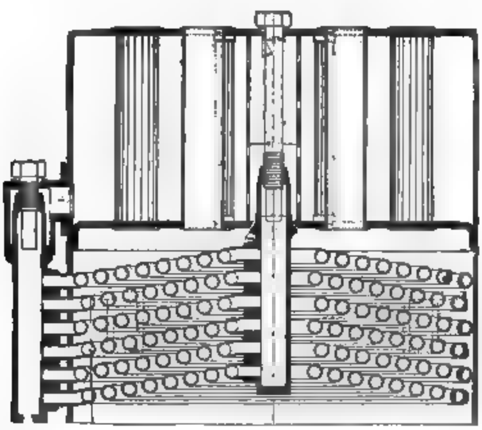


FIG. 340.—The Geneva Carriage Boiler. This boiler consists of several coils of tubing connected at inner and outer extremities to headers, as shown. The water and steam chamber above is constructed like an ordinary flue boiler.

**The Geneva Tubular Boiler.**—Experience seems to prove that those manufacturers who do not use the familiar flue boiler have some form of multiple coil generator, such as are about to be described. Two of the best designed among the coil boilers are the Geneva and the Toledo, named respectively as the carriages they propel. The Geneva boiler has the general characteristics of water-tube boilers, but has been well described as a "combination of tube and flue boilers." It consists of six somewhat conical superposed coils of ⅝ inch seamless cold-drawn

steel tubing, each 17 feet total length, which are pinned and brazed to a header, or manifold tube, both at the centre of the coils and at the outside extremity. These two "headers" serve the same ends as do the head plates of the generator just described; being simply common chambers in which the water may pass from one coil to another, as impelled by the tendency of circulation. Thus the tendency within the inner header is from the lower to the higher coils and within the outer, the reverse. By this means the circulation is directed into its natural channels, and, at the same time, the water within the coils is exposed to the greatest possible area of heat. The heat is also largely economized, as in most tubular generators, by staggering the rows of tubes, thus repeatedly deflecting and breaking up the current of burning gas, as it moves upward to the vent. The water intake is at the base of the outer header tube, and the feed water, as it enters, is urged into the coils by the pressure of the circulating liquid; its temperature being immediately raised by contact with the heated tubes. Both headers are secured by bolts to the drum above the tiers of coils, as shown, and open into it by ports that permit the steam to be given off, and any water escaping to follow the general direction of circulation. This drum is, in fact, a flue shell boiler, being pierced by 16 flues of 1¾ inch diameter, which enable the super-heating of the steam, as the products of combustion pass through them.

The Geneva boiler is 8 inches high, measured from the base to the apex of the coned coils, and the water chamber measures 9 inches from the crown plate, giving a total height of 17 inches. It is also 17 inches in diameter. The engine which it supplies is rated at 6 horse-power, gross, which represents an excellent average of output for its 29 1-3 square feet of heating surface being, in fact, 1 horse-power at the boiler for each 5 square feet.

**The Toledo Water-Tube Boiler.**—The Toledo boiler, although differing considerably in some particulars, is constructed on the same general principles as the Geneva. It consists of an annular water and steam chamber, formed by bolting together two seamless steel shells, suitably shaped, as shown, within which eight slightly coned coils of ⅝ inch steel tubing are attached at top and bottom. The outer connection of each of these coils is near the bottom of the annular space, instead of in a header of

any description and the centre connection is near the top of the chamber. The attachments of all the coils, both at the top and at the bottom, being on horizontal planes, perfect circulation is made possible from the lowest point of heat contact upward. Because of the excellent character of these circulation guides, dry steam is fed to the engine, without danger of priming, the annular steam space serving as a centrifugal separator. The dimensions are 19 by 19 inches, but 1½ inches of asbestos packing gives a total breadth of 22 inches. A heating surface of

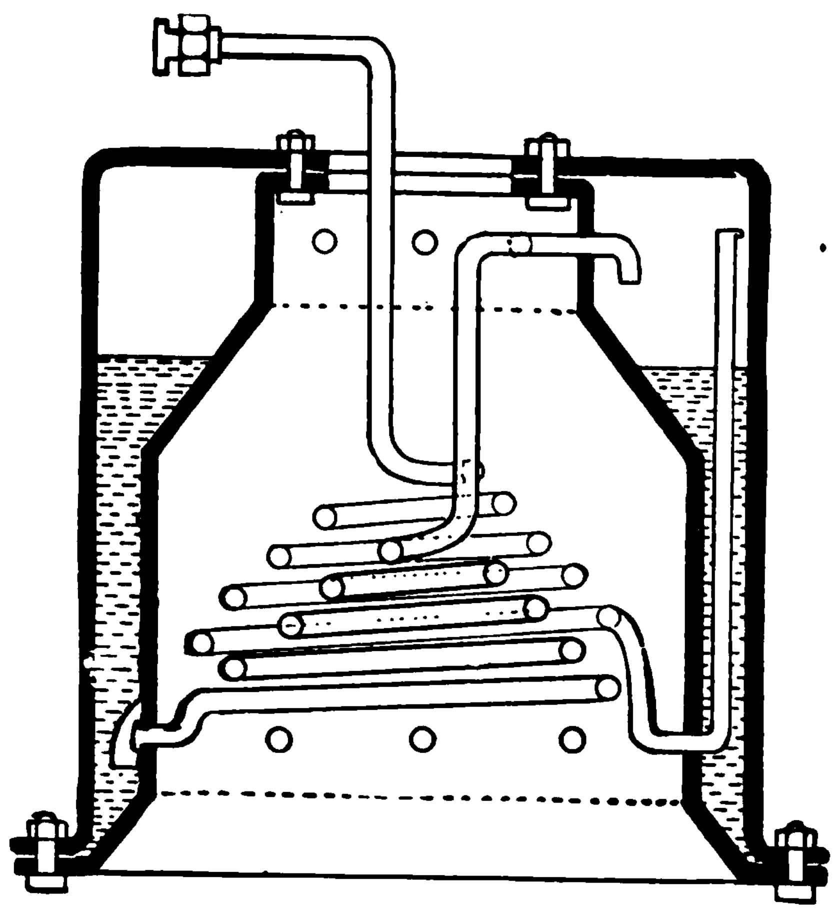


FIG. 341.—**Sectional Elevation of the Morgan Boiler, formerly used on the Toledo Carriage.** The disposition of the coils may be understood from these cuts, also the steam connections through the superheating coil. The sectional view shows the steam superheating and one of the generating coils in position, with connections indicated for other coils. As shown, the steam enters a vertical tube somewhat below the top of the steam space; thence flowing downward, through one of the coils above the fire and out to the engine through the feed pipe.

38 square feet is reckoned, on which is claimed 1 horse-power for every 5 feet, giving a total of 7½ horse-power at the boiler.

Since the two seamless shells, forming the annular water and steam space, are bolted together—no rivets are used—they may be readily taken apart for necessary repairs or cleaning. The coils, also, being connected to the shells by joints of special pattern, may be removed with ease.

**Heavy Vehicle Boilers.**—The achievements noted in the early days of the Nineteenth Century, in producing generators capable

of operating their somewhat unwieldy coaches, has been more than outdone in the present day. Perhaps among these heavy-vehicle generators none have proved more efficient than the Thornycroft, whose details are shown in several accompanying diagrams. Briefly, it consists of two annular chambers, one above, one below, connected together by 168 slightly inclined tubes, set four deep in the tube plates and staggered, as shown.

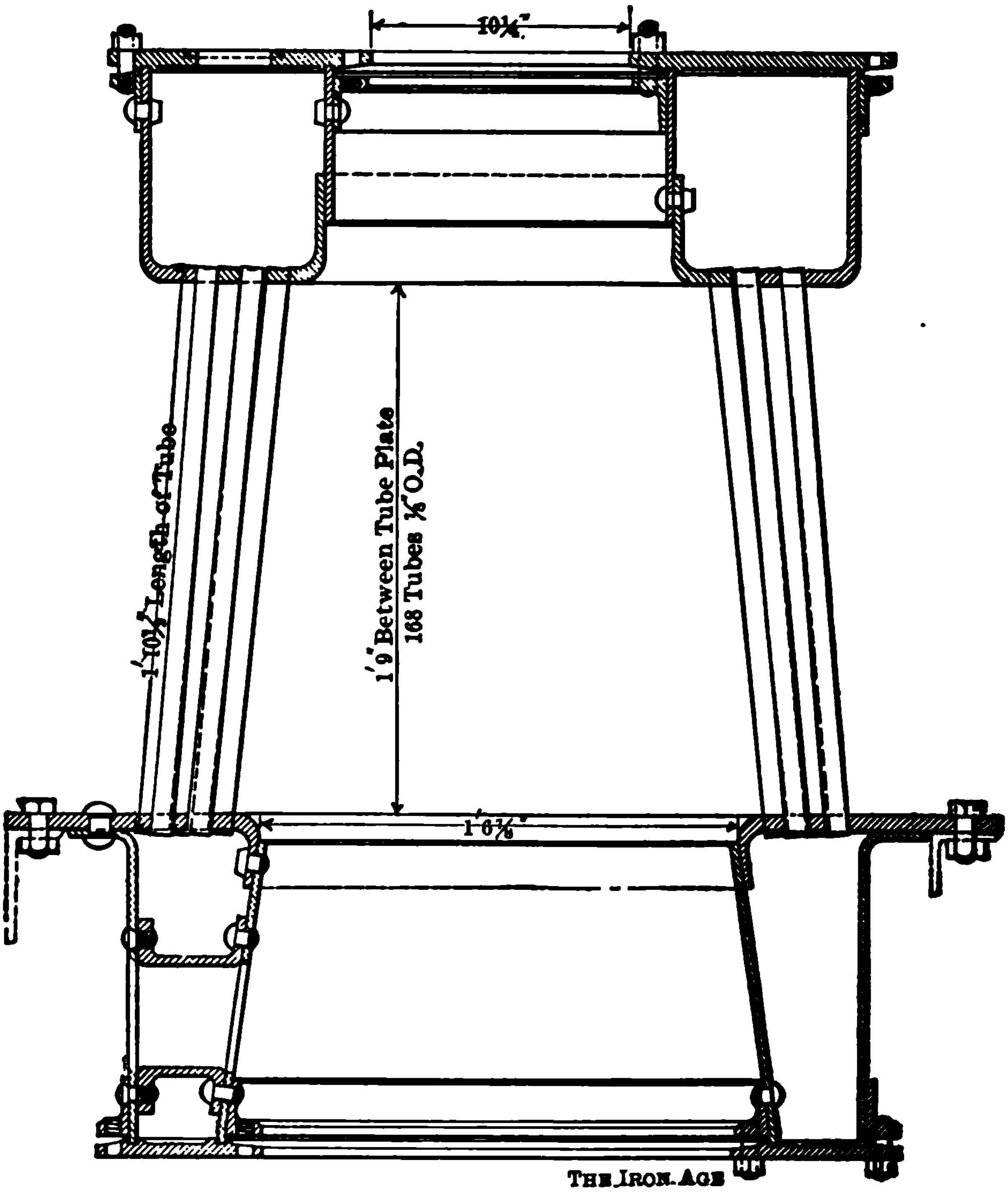



FIG. 342.—The Thornycroft Steam Wagon Boiler.

Both tube plates are steel pressings, and the upper and lower chambers are built up on them by ring-shaped sections, suitably riveted. But the top and bottom plates of the boiler are bolted on, as shown, so as to admit of their ready removal for cleaning or repairs. Fuel, usually coke, is fed to the fire through the aperture in the top of the boiler, and, since the grate is situated

at a point about the bottom of the cut, the fire is confined below the water tubes, touching no part of the generator except the inwardly-sloping sides of the lower drum. Access to the fire, for the removal of clinkers, may be had through the door shown in the lower drum at about the level of the grate.

The entire structure is sheathed by a suitable casing, which confines the gases of combustion, preventing their escape at all points, except the chimney, which is situated to one side. Here a forced draught is maintained by exhaust steam, as in a railroad locomotive, and the smoke and burned gases, having no other vent, are compelled to pass out through the small spaces between the slanting tubes, thus giving off a very large percentage of their heat.

Steam is taken off through the vent shown at the left hand top of the upper chamber, and is fed to the engine through a steam dome. Later patterns of this boiler have also a superheating coil, which carries the steam from the upper part of the chamber to a point directly over the fire, and thence out through this same vent. Water is fed to this boiler by a pump worked by a worm gear on the crank shaft of the engine, or by an injector, when the machinery is not in motion. Two safety valves are also provided; one blowing off into the chimney, the other, situated at the top of the steam chamber, into the air.

With a generator of this description, something over 3 feet in height, 83 square feet of heating surface is obtained on about 2.4 square feet of grate area. Its usual working pressure is about 175 pounds per square inch, with test at 350 pounds, and sufficient steam is developed to give 20 B. H. P. at 440 revolutions per minute, which represents 1 horse-power at the boiler for each 4.15 square feet of heating surface. Such an average indicates a highly efficient generator.

## CHAPTER FORTY-ONE.

### FLASH STEAM GENERATORS.

**Serpollet's Flash Boilers.**—The first real impulse to the modern steam carriage was the invention by Léon Serpollet in 1889 of the famous "instantaneous generator," known by his name. It consisted of a coil of one and one-half inch lap-welded steel tubing flattened until the bore was of "almost capillary width"—this he later increased to about one-eighth inch—and this, sur-

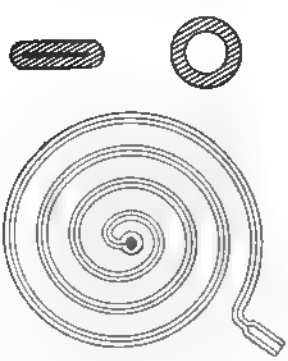


Fig. 343.

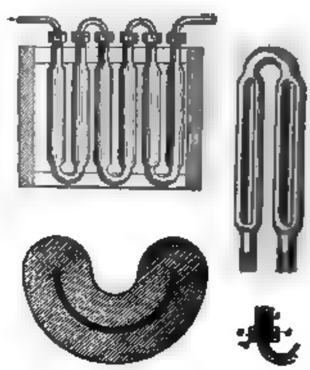


Fig. 344.

Fig. 343.—Earliest Form of the Serpollet Flash Generator; a coil of flattened steel tubing.

Fig. 344.—Second Form of the Serpollet Flash Generator: a series of tubes pressed as shown, bent U-shape and nested; the extremities being connected by joints and bent unions.

rounded by a cast-iron covering to protect the steel from corrosion by heat, was exposed to the fire. The result was an extremely rapid generation of steam, the coil being first heated, and the water being vaporized almost as soon as it was injected into the tube. Later, he improved the efficiency of his coil by corrugating its surface. With such a generator of 108 square inches of heating surface more than one boiler horse power could be developed, the average hourly evaporation being forty pounds of water. The usual working pressure was 300 pounds to the

square inch, but each tube could bear a test of as high as 1,500 pounds. One great advantage lay in the fact that the high velocity acquired by the steam and water in the narrow tube served to keep the surface thoroughly free from sediment and incrustations. For vehicles requiring an additional generative power two such coils were used, one above the other, the water being injected into the lower and the upper one serving to superheat

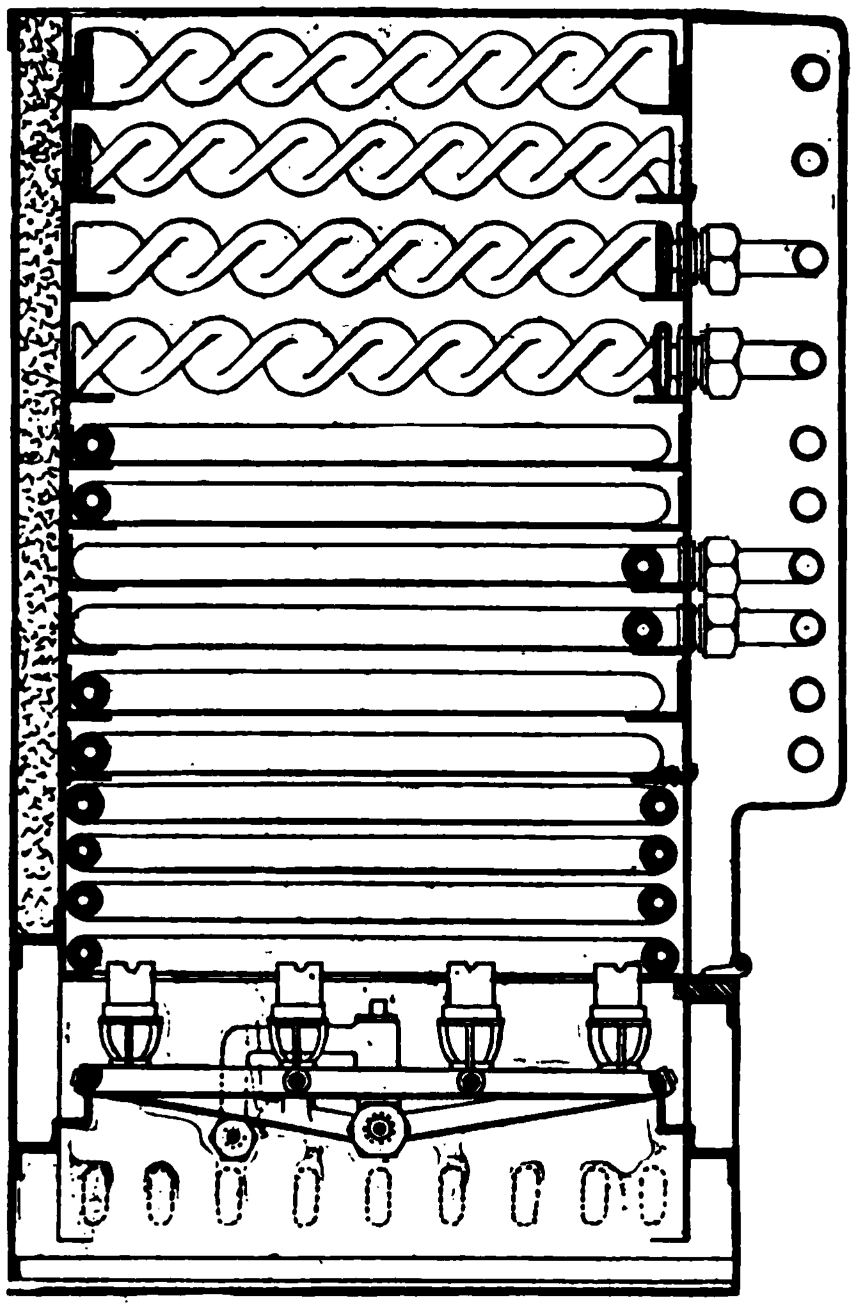


FIG. 345.—Later Form of the Serpollet Flash Generator, consisting of three layers of tubing. The four lowest tiers shown form a coil into which the feed water is injected; the second series of six tiers are arranged "zig-zag," like the nested tubes shown in Fig. 344 ; the third, or topmost, series of four tiers are also arranged "zig-zag," but are flattened and then twisted as shown.

the steam. To stop the engine it was necessary only to shut off the water feed pump, with the result of stopping the generation of steam at once.

In improved boilers of the Serpollet type a number of straight tubes were united by bent joints and nested, the several layers being connected in series. Moreover, each tube length was flat-

tened, so as to form a U-shape, or crescent, in its cross-section, which arrangement greatly increased its evaporating capacity. But the most efficient form was reached in the design shown in Fig 346, which shows three superposed sections of tubing; the lowest, four tiers of coil; the second, six tiers of "zig-zag," the

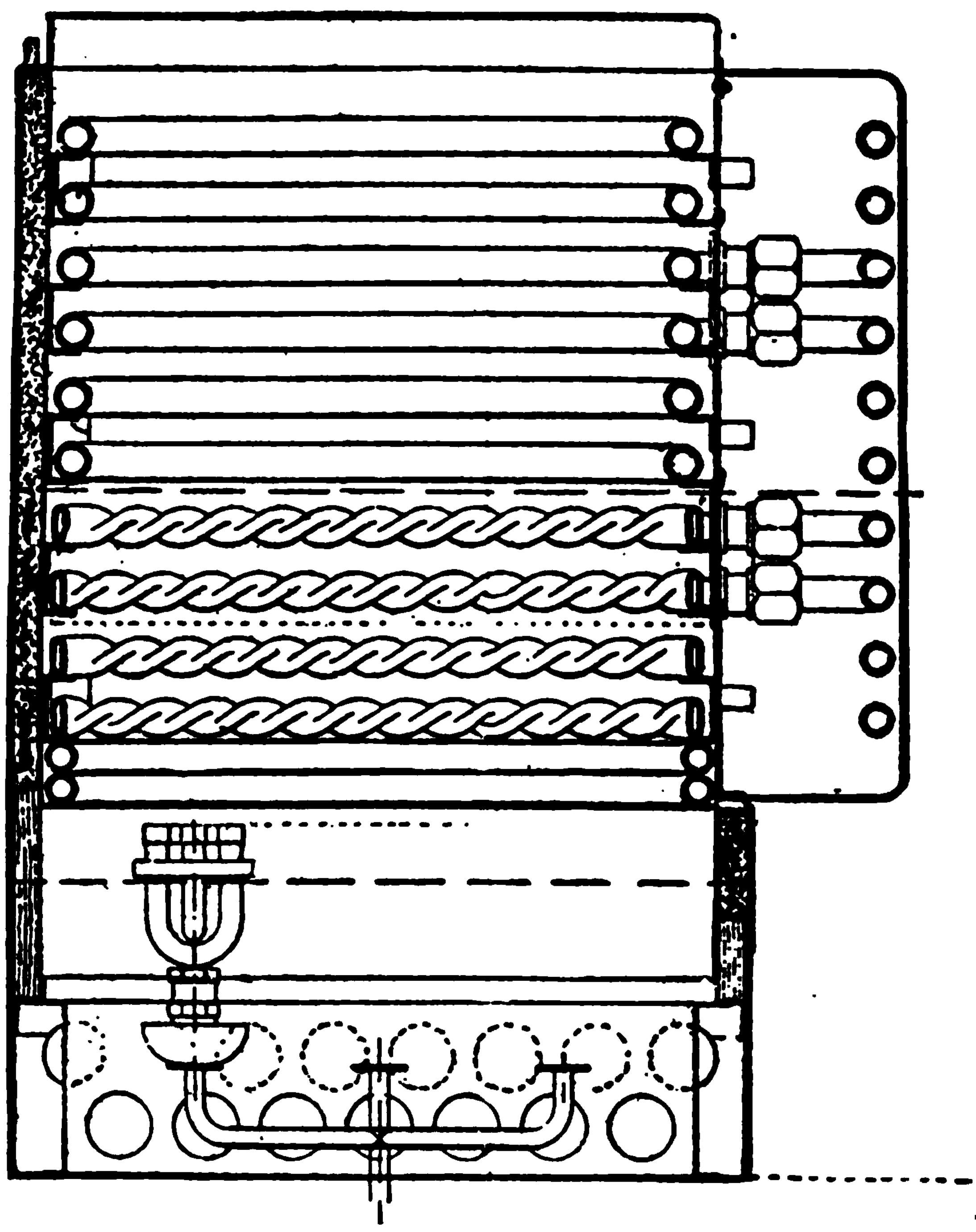


FIG. 346.—Recent Form of the Serpollet Flash Generator. In this type the twisted tubes are placed at the bottom and the "zig-zag" nested tubes at the top. The reason for this arrangement is that twisting the tubes affords a much larger heating surface; hence these tubes are directly exposed to the fire.

successive tiers being staggered, as shown; the third, several tiers of flattened tube twisted to angles of about forty-five degrees. The water is fed to the lowest section, which is immediately exposed to the fire, being thence passed to the second, whose available heating surface is of the greatest possible dimensions, and finally delivered, as superheated steam, from the upper-

most twisted coils. The several sections of tubing are connected together *in series* by bends and unions outside the case, as shown, and the entire generator is enclosed in a double sheet-iron casing packed with asbestos. By the arrangement of the tubing, as here shown, the full power of the heater, in both draught and radiated heat, is utilized, as in the type of boiler shown in Fig. 346, but the circulation of the water is perfectly under control and rapid generation of steam assured. For a six-horse power boiler of this type the outside dimensions, including heater space, are about $2\frac{1}{2} \times 1\frac{1}{2}$ feet, the total tube length, ninety-five feet, and the heating surface, about twenty-five square feet; giving a generator of convenient size for a four-seat road carriage.

**Of Flash Generators in General.**—Following along the lines of Serpollet's famous "flash" generator, with its numerous advantages in point of quick steam, high pressure capacity, freedom from scale deposits, and complete immunity from explosion, several designers of steam carriages and wagons have produced improved "boilers" of similar description. Serpollet's first generator, as applied to his light steam carriage of 1889, was merely a coil of flattened tubing. Later two such coils, connected in series, formed his generator, and finally the complicated trains of coils and bent tubing. In the latest generators described the water is fed to the lowest tier of tubing, and the steam is taken off at the top, as in the several types of coiled water-tubed boilers, already described.

The contrary procedure is followed in most of the really successful flash generators produced by other inventors. The Blaxton generator feeds from the lowest water coil, but the Simpson-Bodman, White, Automobile Manufacturing Co., and others feed from the top and superheat the steam in the lowest coils. This seems to be the most logical process for this type of generator, since, as the water is explosively vaporized by contact with the heated tubes, it follows that the progress should be from the lowest to the highest temperature, vaporizing and superheating the steam, rather than allowing it to follow a course from higher to lower temperature, with the accompanying consequence of loss of heat. By making the tubes of sufficient capacity to vaporize a good quantity of water, surprisingly high temperatures may be obtained in a short time and high power

engines may be driven with perfectly dry steam. In these particulars the flash generator is superior to a boiler of any type, although it is probable that its use for light carriage purposes will be very limited.

**The White Flash "Boiler."**—Among the light steam carriages equipped with flash generators may be mentioned those

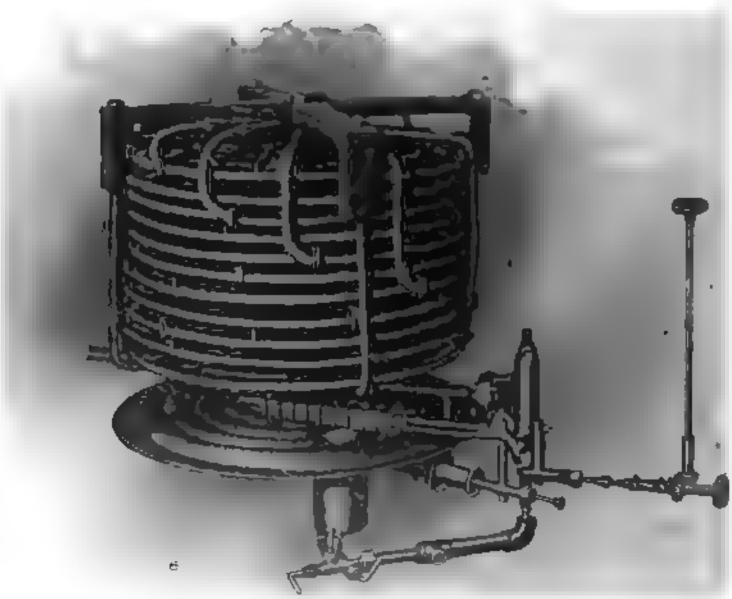


FIG. 347.—Diagram Illustrating Arrangement of the Vaporizing Coils of the White Flash Generator, Elevation. The water is fed into the centre of the top coil, flowing all around that coil and, *in series*, through every other coil in succession. It is "flashed" into steam somewhere above the lower coils, being taken off from the bottom one. The steam pipe rises to the top of the generator, as shown.

constructed by the White Sewing Machine Co., and the Automobile Manufacturing Co., the latter an English concern. The White generator consists of twelve superposed plane profile coils of quarter-inch seamless steel tubing, which are connected continuously from top to bottom. The water, under impulse from a

plunger pump operated from the crosshead of the engine, as in most steam carriages, enters the top coil at the centre point, flowing thence around the tube to the outer extremity of the coil and over again to the centre of the coil next below. The same connection of outer and centre extremities is maintained throughout the entire series of coils until the bottom one is reached. Here the connection of the outer extremity is to the top of the generator case, where is the steam out-take. This arrangement may be readily understood on examining the diagram.

The water, pumped into the top coil, passes entirely around, and thence through each coil continuously, until the bottom coil is reached. Somewhere in the downward travel it becomes vaporized, and by the time it emerges from the last coil it has become superheated steam. The amount of water actually fed to the coils is determined by a diaphragm regulator, which controls a by-pass valve, operating to return any surplus feed to the tank. The feed is thus interrupted when the pressure falls—which fact indicates the presence of too much water in the tubes, since the amount of contained water and the total pressure per square inch are in inverse proportion. By this means the operation of the generator may be maintained automatically at a uniform point; its output efficiency and the rapidity of steam generation being dependent on the amount of fuel consumed by the burner, which fact determines the heat of the coils.

The pressure is indicated by an ordinary steam gauge, which shows a normal working pressure of 200 pounds per square inch, that being the point at which the tension of the regulator spring is adjusted. The safety valve, however, is adjusted to blow off at 500 pounds, a pressure which the coils are said to be able to withstand. Under usual conditions of operation the steam may be superheated to about 800 degrees. As in all flash generators, no water is fed to the coils when the engine is not working, and the first essential act in starting work is to begin feeding by hand, which it is necessary to do no longer than to provide for the generation of steam for the engine. The generator is of the usual size of light carriage boiler, when encased in its sheet iron and asbestos packing cover, and runs a 6-horse-power engine.

The automatic regulator used on the White steam generator is a true thermostat device, like that used on the Blaxton generator, although regulating the fuel supply rather than the burner flame.

Its position and connections are shown on the figures of the White water feed system, where it is designated as *Q, R, S.* As shown in the accompanying figure, it is constructed as follows: A tube, *A, A, A,* extends entirely through the diameter of the generator, forming, in fact, the connection between the two lowest coils of the White steam generator, and being connected at one end on the point, *Q,* and at the other on the sleeve there shown. Within this tube, *A,* is another one, *B,* secured, as shown, to the head piece at the right hand end of the tube in the figure. This second tube is preferably of copper, and around it, within the tube, *A,* the steam circulates freely between the two lowest coils, so long

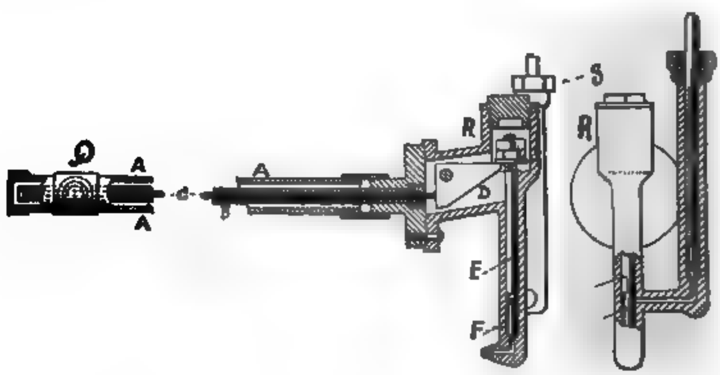



FIG. 848.—The White Thermostat Fuel Feed Regulator. A is a tube extending clear through the body of the steam generator and forming the connections of two of the coils, as at Q. B is a tube contained within A, and around which steam circulates; C, a rod contained within B; D, a bell crank regulating the valve, E, as C lengthens with heat; F, the point of the valve. R is the valve chamber, and S the gasoline inlet chamber regulated by a needle valve on a screw-threaded rod.

as the generator is in operation; thus determining its temperature and consequent expansion. Within this second tube, *B,* again, is the rod, *C,* preferably of iron or steel, whose ratio of expansion is smaller than that of copper for all usual boiler temperatures. This tube, *C,* bears upon the bell crank, *D,* normally holding it in the position shown. When, however, the temperature of the steam or air within the tube, *A,* has reached a certain predetermined maximum, the tube, *B,* of copper, expands accordingly, lengthening in the direction at the left of the figure, on account of being rigidly secured to the head at the right. The result is that the linear expansion of *B* and *C* being unequal, *C*

is drawn away from the bell crank, *D,* with the result that the rod, *E,* is allowed to fall accordingly, decreasing or quite closing the needle valve at *F.*

**The Blaxton Flash Generator.**—The Blaxton generator, although differing in several important particulars, is constructed on the same general theory, consisting of a number of super-

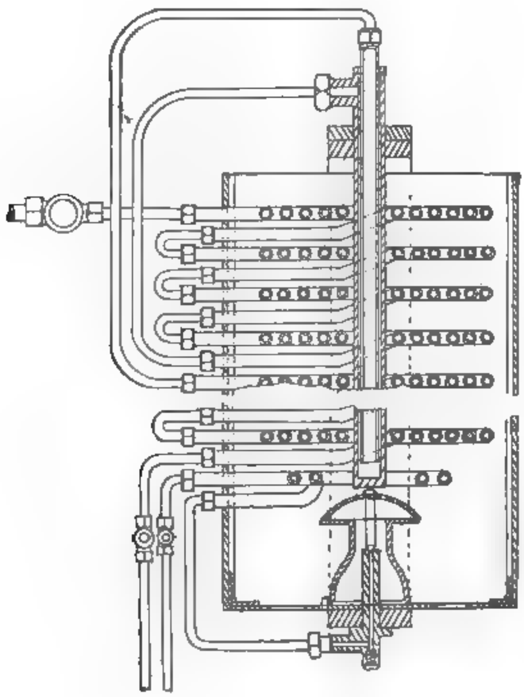


FIG. 349.—Sectional Elevation of the Blaxton Flash Generator.

posed plane-profile coils of tubing, through which the water is passed in series, from the lowest coil to the top, where it is taken off as steam. As shown in the figure, the water fed from the pump passes direct to the centre of the lowest coil, thence around to the outer extremity, and to the centre of the second coil. The connections between the coils of tubing are made by nut joints and unions outside the casing. The feed water is pumped in by

hand until sufficient steam to operate the engine is obtained, precisely as in other flash generators.

The particularly interesting feature of the Blaxton generator is the device employed for automatically maintaining the consumption of fuel and of steam at one ratio. As shown in the diagram, the fuel oil is pumped into the short coil placed lowest in the case, and, being vaporized by the flame, passes around to the burner. Directly above, and nearly touching, the burner is a vertical tube, closed at the lower end and containing a second somewhat shorter tube.

The water, in process of vaporization, passes from the outer extremity of one of the coiled elements directly into the inner of these two tubes, the circulation being completed when it passes up between the inner and outer tubes, through a joint, into the centre of the coil next above. By this means the temperature, and consequently the length, of the outer tube is regulated. For, so long as the feeding of cold water continues, the water or steam, passed through this tube, absorbs a large percentage of its heat, thus preventing unusual expansion lengthwise, but, when the supply is cut off, or when, from any cause, the heat becomes too great, the tube elongates, and, pressing down upon the gland of the burner, closes the needle valve that controls the fuel supply. By this means the life and usefulness of the generator is prolonged, as much as possible, since overheating is prevented by the constant closing of the fuel feed valve. The Blaxton generator is thus rendered more highly efficient than most of the average "flash boilers," whose greatest drawback is the constant tendency to burn out, if left long exposed to heat when no water is being fed to the coils.

The generator herewith illustrated measures 5 feet 9 inches in height and is 3 feet square. It contains 126 square feet of heating surface, has a normal working pressure of 200 pounds per square inch, and can propel an engine of 25 horse-power. This average on heating surface is about equivalent to that of a good water-tube boiler, although here steaming is more rapid.

# CHAPTER FORTY-TWO.

## THE TESTING AND REGULATING ATTACHMENTS OF STEAM BOILERS.

**Boiler Attachments: Try-Cocks and Water Glass.**—In operating a boiler of any design it is essential both for safety and efficiency that the engineer should be kept constantly informed on the level of the water and the pressure of the steam. For this reason boilers are fitted with try-cocks, water glass and steam gauge, all of which are depicted in accompanying figures. There are usually three try-cocks, as shown, the upper one intended for steam, the second at the working level of the water, and the third at a fixed point above the fire line. In conditions of uncertainty in the action of the water glass the engineer may find out whether the water level is too low by opening the lower cock, or may find if it is too high by opening the two upper ones. In making test it is necessary to leave the cock open sufficiently long to discover whether all steam, all water, or a mixture of both is escaping. In large boilers it is desirable thus to open the try-cocks several times a day.

The water glass, or water column, furnishes a ready means for determining the exact height of the water in the boiler. It consists of two cocks opening into collars arranged to be connected by a length of glass tubing, as shown in the figure. By opening these cocks the height of the water may be seen in the glass tube. Since it is such an important consideration in boiler operation that the water level should be constantlv watched, it is necessary that the water column should be placed where the engineer may constantly observe it. Thus it is that, in steam carriages it is disposed in the side of the body beneath the seat, its condition being readily observable by the driver by reflection in a small mirror set to one side of the dashboard. Lamps are also arranged behind it, so that the level of the water may be observed at night.

The water glass also gives information on the condition of the water within the boiler, as when oil or scum has collected on the surface, causing foaming. Then the uneven fluctuations in the

water level indicate the condition beyond doubt. When this condition is noted it is time to blow off the boiler, or, at least, to observe carefully its operation.

**Troubles with the Water Glass.**—Troubles with the water glass that must be constantly guarded against are stoppage by sediment and the breaking of the glass tube. The former diffi-

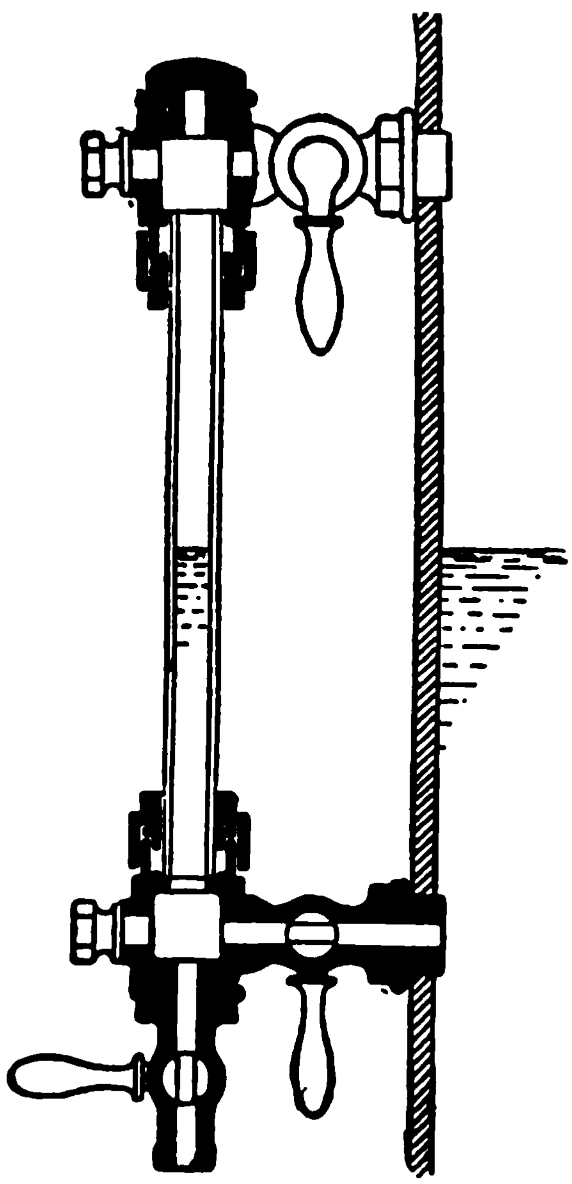


FIG. 350.

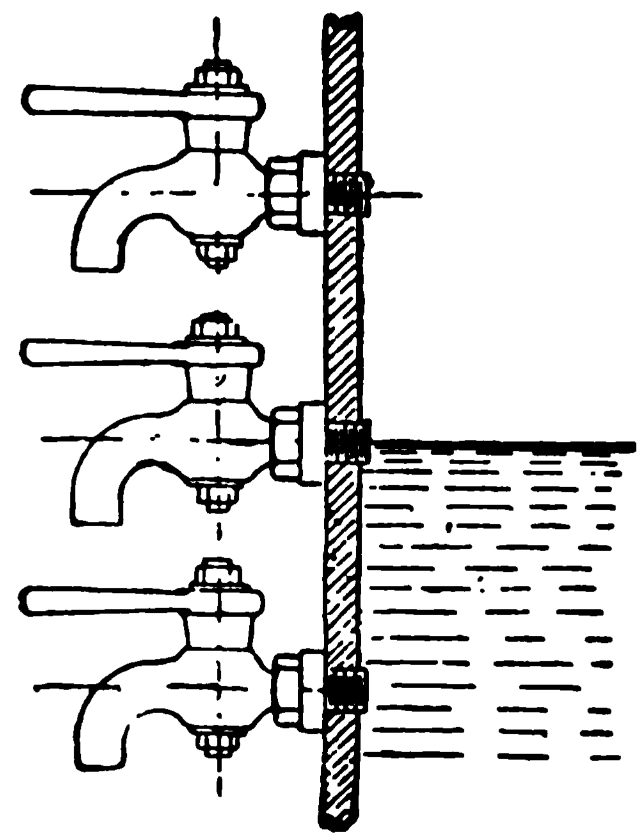


FIG. 351.

FIG. 350.—Sectional view of a water glass, as used on large boilers, showing water level and sections of stop-cocks, drain-cock, tube packing and retaining nuts.

FIG. 351.—Section on boiler shell showing the designed position of the try-cocks: the center one coming at about the average water level.

culty may generally be remedied by closing the lower cock and allowing the steam from the upper one to blow through the drain cock shown at the bottom. In case the glass tube be broken it is necessary only to close both cocks, and insert a new tube in the collars, having first removed the nuts and packings at top and bottom. In order to obviate, as far as possible, breakage of the glass it is necessary to avoid too sudden changes of tem-

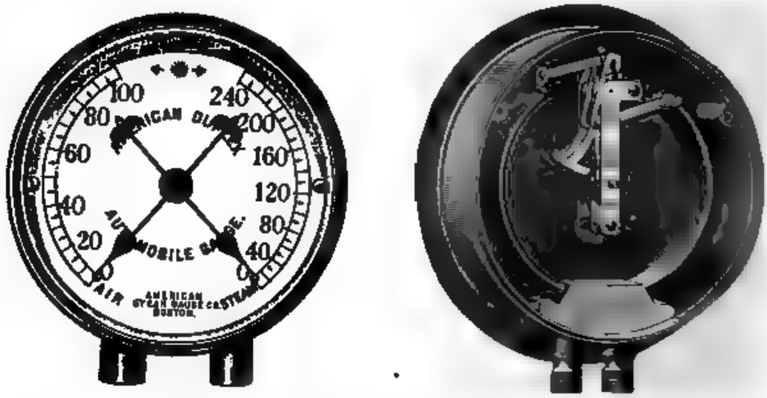
perature in the column, when first opening the cocks, after getting up steam.

Most of the water glasses used on steam carriage boilers have self-closing valves, which operate to prevent the escape of steam in case the glass is broken. In the use of these valves particular care is needed, since they are very liable to be clogged with sediment or incrustation, causing false indications of the water level and enabling the boiler to be burned out before the driver knows that anything is wrong. Several carriage owners, in the writer's experience, have had these valves removed, and contented themselves with closing the cocks every time the glass is broken. This may be a rather exceptional experience, but it is extremely desirable, if not imperative, to verify the water glass reading by the try-cocks before starting the carriage.

The water glass is an important piece of mechanism, and cannot be too closely observed and cared for. Skilled engine drivers take its record constantly, and so very important is it that no error regarding the water level should be made that some inventors have proposed using colored floats to attract the driver's eye, and enables readier reading of the record. A supply of glass tubes should always be kept on hand in a steam carriage so that breakage may be immediately repaired. Also, every possible precaution should be adopted to prevent the accumulation of sediment that might obstruct the free passage of the water into the glass. It is well to clear the tube by flushing with steam at frequent periods.

**The Steam Gauge.**—As a means of determining the power output, a steam gauge is attached to all well-appointed boilers. This device indicates on a dial the degree of pressure generated within the boiler. Steam gauges are constructed with one of the two varieties of internal mechanism. In the first variety the steam bears upon a diaphragm, regulated to yield in proportion to the pressure exerted. The second variety operates through the tendency of a flattened and bent metal tube to straighten out under pressure of the steam or gas within it. As shown in an accompanying figure, a tube, flattened to an ellipsoidal cross section, is connected by one end to a steam pipe leading direct from the boiler. When the cock is opened, steam is admitted to the tube,

its pressure tending to change the flat section to one more nearly round, and in the process causing the tube to begin uncoiling itself in the direction of a straight line conformation. Hence the other end of the tube, attached, as shown, to a link connected to a lever bearing a toothed segment, tends to move, causing the link to move the lever. As the lever is dragged by the link, the toothed segment actuates a pinion carrying the hand of the dial on its spindle, thus indicating on the dial the pressure at work in the tube.




FIGS. 352, 353.—Dial and Interior View of the "American" Duplex Combined Steam and Air Pressure Gauge for Use on Steam Carriages. The dial has two hands; one of them attached to a sleeve which works over the spindle carrying the other, in the same manner as the two hands of a clock are hung. As may be readily understood, the two hands work in opposite directions, one clockwise, the other counter-clockwise, from zero to maximum on their respective scales. The sectional view shows the mechanism by which this result is accomplished: two separate inlets, for steam and air, respectively, two distinct flattened and curved steel tubes, each attached at its end by a link to a lever and toothed sector working on the toothed pinion concentric with the pivot of one of the hands. The two flattened tubes, of course, have different tensile ratios, causing them to tend to straighten at different pressures. Hence the steam hand records a maximum pressure of 240 pounds, while the air hand records a maximum pressure of 100 pounds.

**Cause and Danger of Excessive Pressures.**—Since every boiler is calculated to supply steam to its engine at a certain maximum working pressure—with light steam carriage boilers the usual working pressure is between 180 and 200 pounds—the driver can readily find from his gauge whether or not full power is being generated. Exceptionally high pressures under working conditions indicate a danger point, and in small boilers they are very often due to a low water lever, which, unless reme-

died, will result in burning out. A carriage boiler holding a proper supply of water cannot derive sufficient heat to generate pressures above a certain fixed point, because, as will be explained presently, the fire is automatically regulated. If, however, the water has become exhausted, even though an excessive pressure acts to shut off most of the fuel supply, the metal of the boiler will become sufficiently heated to collapse the tubes. It is the "dry heat" that is most to be feared in boilers.

**Safety Valves; Construction, Theory and Operation.**—The design of the argument up to this point is to satisfy the reader that explosion in a steel-shell, copper-flued carriage boiler is very nearly impossible, and, further, that moderate care and watchfulness can prevent the burning out or collapse of the flues. The unskilled engine-driver is amply protected, if he only exercises reasonable prudence by the automatic burner regulator, the automatic low water alarm, the water glass and steam gauge in plain sight, and lastly by a safety valve adjusted to blow off at the proper pressure.

A safety valve is simply a valve of ordinary description, arranged to close a steam pipe outlet, under pressure of a weight or spring.

The safety valves used on steam carriages are constructed on the same general principles as any of the spring valves used on locomotives, or other boilers. They are usually known as "pop" valves, from the fact that the steam in lifting the valve from its seat usually makes a "pop" or sudden detonation. As a usual thing carriage valves are adjusted to a fixed pressure, which is never disturbed.

**The Blow-Off Cock.**—This is an important attachment of all boilers, furnishing a ready means of removing the water from the boiler under pressure of its own steam, which is called "blowing-off." It is also used in some carriages for attaching a hose to fill the boiler at starting, or for injecting water for cleaning the interior. It is usually closed with a box nut for receiving a wrench, but sometimes by a cock, as in large boilers.

# CHAPTER FORTY-THREE.

## BOILER FEEDERS AND WATER LEVEL REGULATORS.

**Of Boiler Feeders in General.**—There are two different kinds of device for feeding water to steam boilers: plunger pumps operated by the engine or by a separate cylinder; and injectors, which raise and feed the water by a steam jet from the boiler itself. Injectors are largely used for locomotives, marine and stationary boilers, but to the present time almost not at all in steam road carriages. The principal reason for this is that the valves and apertures in an injector, suited for a light carriage boiler, would have to be made so small that they would be constantly clogged with dirt and sediment, hence rendering the instrument inoperative. Furthermore, when in operation, an injector would be liable to fill the boiler too rapidly, while the pressure remained sufficient to raise the water, thus causing priming; and, if shut off until the water level had fallen considerably, would cause damage to the boiler by flooding it, while in an overheated condition.

**Plunger Pumps and By-Pass Valves.**—The plunger pumps used to feed steam carriage boilers are most often operated from the cross-head of the engine. Consequently, so long as the engine is in motion, water is steadily pumped into the boiler. When, as shown by the water-glass, the level is too high, the by-pass valve may be opened, and the water pumped from and back again to the tank. In some carriages the by-pass is always operated by hand; in others it is also controlled by some kind of automatic arrangement. The automatic control of the by-pass is extremely desirable, particularly since unskilled engineers most often have charge of carriages and are exceedingly liable to forget the small details of management. On the other hand, many automatic devices get out of order altogether too easily, and leave the carriage driver to exercise his skill and judgment at an unexpected moment.

In addition to the danger of flooding the boiler, the opposite embarrassment often occurs—owing to some disarrangement the pump may fail to feed enough water to the boiler, or may not operate at all. Then it is necessary to use a supplementary feeder, generally a hand pump, or a steam pump operated by a separate cylinder. Such supplementary steam pumps and injectors are commonly arranged to start automatically, as required, but may also be started by a hand-controlled valve. Another advantage involved in the use of automatically controlled steam pumps is that water may be fed, as required, to the boiler, after the engine

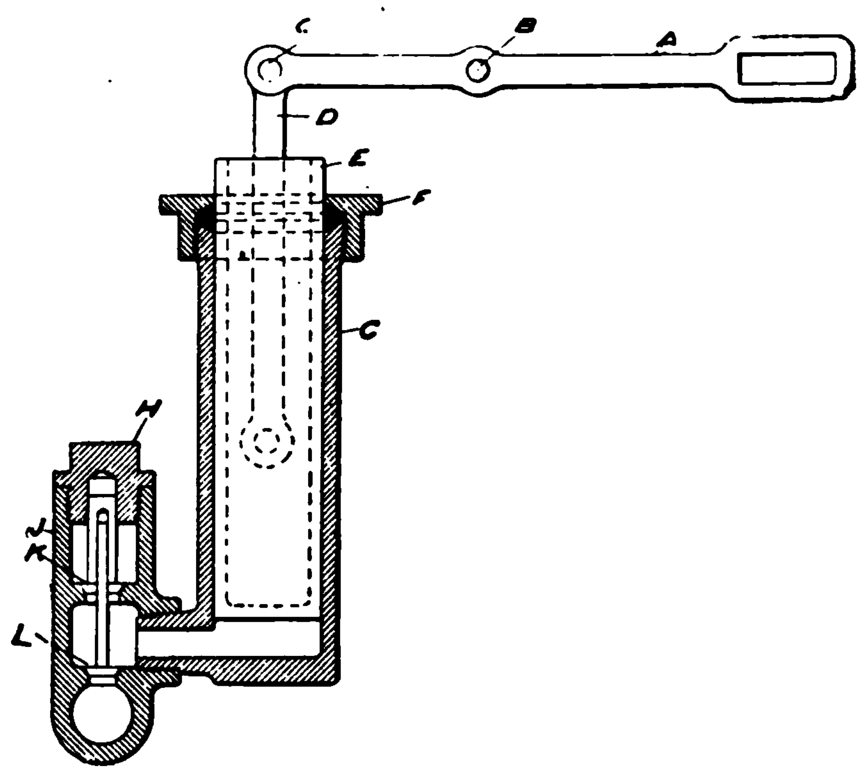



FIG. 854.—Section of a Type of Plunger Feed Pump. As is obvious, the valve opened by suction of the up-stroke is closed by compression of the down-stroke, and *vice versa*. This pump is equipped with a double, or compound, valve, which, as may be seen, secures perfect balance in operation with the simplest possible constructions. The stem of the suction valve enters a bore in the stem of the outlet valve. Referring to the lettered parts: A is the pivoted lever working the pump from the crosshead of the engine; B, the fulcrum point; C, the attachment of the piston rod, D; E, the trunk plunger; F, the packing cap; G, the pump cylinder; H, nut on the valve chamber port; J, the valve chamber; K, water outlet valve; L, water inlet valve.

has ceased motion, and it is desirable to leave the carriage standing with steam up. In this condition, however, a very small amount of water is needed, except under unusual conditions.

**Operating the By-Pass Valve.**—The driver of a steam carriage must constantly watch the water-glass in order to inform himself as to the water level in the boiler. On noticing that the level is too high, or is rising too rapidly—the proper level is generally about two-thirds up the glass—he opens the by-pass

valve by turning a small wheel placed near the throttle lever beside his seat. This act, as already suggested, turns the water forced by the pump back again into the feed tank, a three-way cock controlling its travel.

If, after the water has been led from the boiler for some time, the level begins to sink, it is necessary only to close the by-pass valve, thus resuming the feed. If, from any cause, the pump seems unable to keep up the water level in the boiler, and the reading of the water-glass is verified by the try-cocks, thus showing that it is working perfectly and is unclogged with sediment, a few strokes of the auxiliary hand pump will suffice, if no automatic steam pump be attached to the carriage.

**Troubles With the Pump.**—Since the small water pumps attached to steam carriages are of the simple plunger type, failure to supply sufficient water to the boiler may generally be attributed to loosened packings or to clogged check valves. The rapid sinking of the level in the water-glass will indicate trouble with the pump, except when ascending a high hill. In the latter case the fall of level may reasonably be attributed to the unusual steam consumption. Under usual circumstances, the trouble is due to loosened packings, and this trouble may be remedied by inserting new packings, although particular care should be exercised, so as not to pack the plunger too tightly and cause breakage. If it seems evident that the falling water level is due to clogged check valves—this is a comparatively rare occurrence—the fire should at once be extinguished and the check valves opened and cleaned.

**Flash Boiler Feeders: The Serpollet System.**—The feeding apparatus for shell and water tube boilers is to be adjusted, either automatically or by hand, solely with reference to the maintenance of a proper water level. With the feeding of flash generators, however, the operation of automatic devices depends solely upon maintaining a certain predetermined pressure and temperature, which are properly in ratio to the quantity of water being vaporized in the tubes, as is not necessarily the case with generators of other types. It is possible, therefore, to maintain the feed at the proper rate and quantity by automatic pressure regulators, such as are used in connection with steam carriage burners, or else by some system of uniform regulation for fuel and water pumps.

The latter theory is adopted in the Gardner-Serpollet system. As shown in the diagram, the fuel is fed to the burner, and the water to the boiler, through pumps, both of which are operated from the same shaft. The fuel pump is smaller than the water pump and its stroke is also shorter, as is obviously necessary. This is accomplished by the use of a stepped cam, consisting of a row of eccentric discs, of varying eccentricity, which, placed upon the rotating shaft, may be slid in either direction, thus vary-

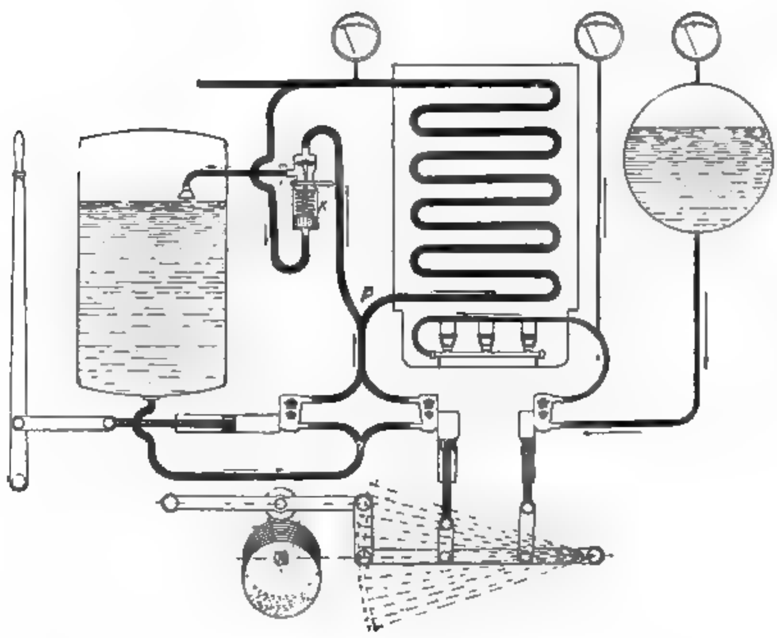


FIG. 355.—The Serpollet Water and Fuel Feed System. The method of hanging the stepped cam controlling the pump stroke may be here understood.

ing the lift. By shifting the cam inward toward the driving spur the strokes of both oil and water pumps may be varied from zero to maximum; the cam surface being efficient in giving a greater or shorter inward stroke, and in permitting an outward stroke of equal length under stress of the spiral spring attached below the pump-operating lever. These operations may be readily understood by a study of Fig. 356, which is sketched from the machine actually in use.

The liquid fuel and the water, being thus varied in the amounts given forth by the pumps, are forced, the one into the vaporizing tube, passing over the burner, the other into the flattened and nested tubes of the generator. By this means the heat is increased in ratio with the quantity of water injected, and the working pressure may be regulated to any desired limit. When, however, the pressure has risen above a certain fixed point—it is generally fixed at about 355 pounds per square inch—it is able to open the spring safety valve, shown attached to the steam pipe, thus also opening the by-pass, so that the water from the feed pump is

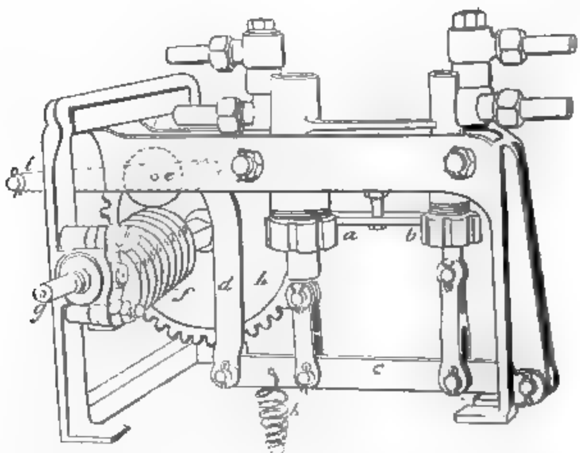



FIG. 356.—Serpollet's Fuel and Water Pumps. The water pump, *a*, and the fuel pump, *b*, are operated from the lever *c*. This is given an up-and-down movement by the link, *d*, whose stroke is varied by the stepped cam, *f*, on which bears the roller, *e*, on the rod pivoted at *i*. The rotary movement of the cam shaft, *g*, is imparted by the spur wheel, *h*.

thrown back into the tank. The water from the pump may be forced through the spring valve, instead of into the generator, by the closing of a check valve at *P*, under steam pressure. The connections may be readily understood from the diagram, which also shows a hand-operated pump for making the initial injection of water into the generator tubes previous to starting the engine.

The construction and operation of the automatic by-pass regulator, or "safety valve," may be understood from Fig. 357. Strictly speaking, a flash generator needs no safety valve, but

its operation demands some method of preventing flooding when the pressure is high enough.

**The White Flash Boiler Feed System.**—The water-feed system of the White steam carriage flash generator is based on a different theory, although the by-pass valve is controlled by a spring and pressure device, as with Serpollet. The details of the system may be understood from the accompanying diagrams,

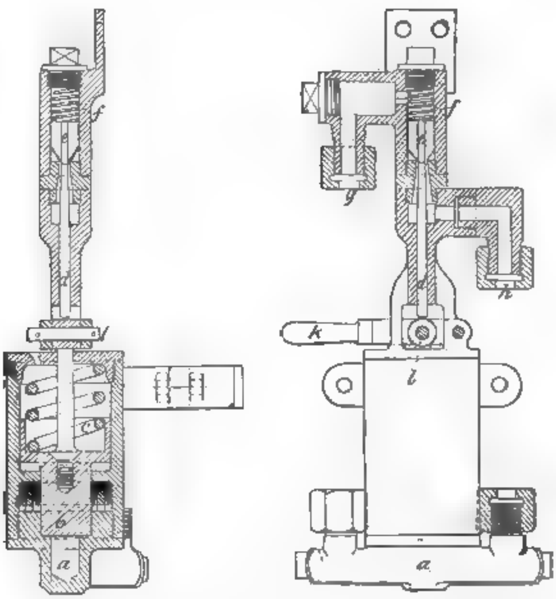



FIG. 357.—The "Safety Valve," or Automatic By-Pass Regulator of the Serpollet Boiler Feed System The steam, admitted through the tube, *a*, after it has reached a certain pressure, opens the valve, *b*, compressing the spring, *c*. By this action the rod, *d*, forces up the valve, *e*, and the spring, *f*, thus enabling the water from the pump to pass from the pipe, *g*, through the pipe, *h*, to the water tank.

which exhibit all the essential features. A plunger pump, *A*, operated by a pivotal lever from the crosshead of the engine, *B*, forces water from the tank, *C*, through the pipe, *D*, which, however, divides into two branches at the point, *E*, one portion of the water being forced by the pump through the pipe, *F*, to the coils of the generator, *G*. The pipe, *F*, has the air-chamber, *H*, located, as shown, between the pump and the steam generator. An-

other portion of the water coming through the pipe, *D*, passes through the pipe, *J*, which communicates with the lower chamber of the pressure regulator, *K*, to be described later. Since the

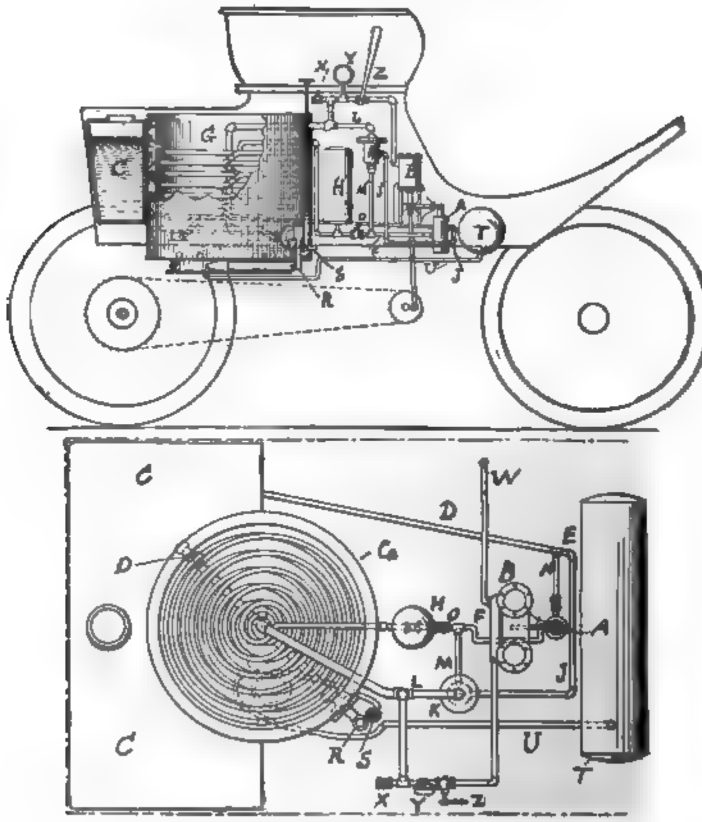



FIG. 358.—Diagram of the Fuel and Water Feed System of the White Steam Carriage. A is the water pump operated from the crosshead of the engine, B. C is the water tank; D, a pipe leading to the pump, and branching off at E, as shown, into J and N. F is the boiler feed pipe leading through the check valve, O, and the air chamber, H. K is the automatic by-pass regulator; L, a pipe leading steam from the generator, G, and allowing the water to circulate through F, M, K, J, E, N, A, whenever steam pressure rises high. X, the pop valve; Y, the gauge; Z, the throttle; T, the fuel tank; U, the fuel feed pipe; Q, R, S, the fuel regulating and vaporizing system explained later.

regulator, *K*, is operated only when the steam pressure has reached a certain predetermined point, when the by-pass valve is opened, the pipes, *F* and *J*, are not in communication so long as

the pump, *A*, operates to feed water to the coils of the generator, *G*.

The regulator, *K*, is constructed and operated as shown in an accompanying diagram. It consists of two chambers, *a* and *b*, which are put into communication on the opening of the valve, *c*, normally closed by the spiral spring, *d*. The rod carrying the valve, *c*, is attached at its opposite end to the head, *e*, which bears

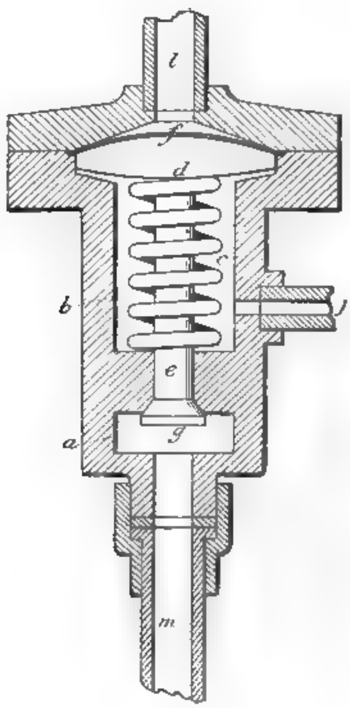



FIG. 359.—Section of the Automatic Boiler Feed Regulator of the White Steam Carriage.

against the metal diaphragm, *f*, held between the casing of *a* and *b* and the cap, *g*. The operation is obvious. The port, *l*, shown just above the diaphragm, *f*, is connected direct to the generator by the pipe, *l*. When, therefore, the steam pressure has risen above a certain predetermined point, which means that a greater force is exerted on the upper face of the diaphragm, *f*, than

comes through the head, *e*, from the spring, *d*, the valve, *c*, is opened, making free communication between the chambers, *a* and *b*. Since, now, the ports, *j* and *m*, are on the pipes, *J* and *M*, which are connected in the system, as shown, the opening of the valve *C*, means that the water circulation from the pump, *A*, is through the pipes, *F*, *M*, *J*, *N*; all water being shut from the coils of the generator by steam pressure at the check valve, *O*.

As soon as the steam pressure again falls to normal, the valve, *c*, is closed by the spring, *d*, and the check valve, *O*, in *F* is again opened, admitting water to the coils of the generator under pump pressure.

In connection with this system of controlling the boiler feed, there is a thermostat regulator, shown at *P Q*, for varying the amount of gasoline fuel fed to the burner, or cutting it off entirely. This, however, will be explained in the chapter on burners and fuel feed regulators.

**The "Victor" Steam Air and Water Pumps.**—The automatic auxiliary feed pumps used on the "Victor" carriage and shown in section in the accompanying illustration are operated on a principle which has already been applied to the steam air pumps used in connection with the Westinghouse air brake on many American railroad locomotives. As will be seen in the illustration, two such automatic pumps are used on this carriage, the one being intended as an auxiliary feed pump for the boiler, to be used in case the regular feed pump, which is of the double-plunger type, being geared to and operated from the rear axle, should from any cause cease to operate. The other pump is used for maintaining the acquired air pressure in the fuel tank. The steam is admitted through the port marked "steam inlet" in the accompanying diagram; this port leads into an elongated chamber running the full length of the cylinder, and of somewhat enlarged diameter towards the top. Within it, as may be seen is a vertical rod, carrying a piston valve at either extremity. The steam on entering, of course, bears against these pistons, and since the upper one of the two is of the largest diameter, it forces it into the position shown in the cut, thus opening the port into the upper end of the cylinder, and forcing the piston downward. The downward stroke continues until a shoulder at the lower end of the rod, *B*, strikes the nut fixed above *G*, opening the

valve, *D*. Communication is thus established between the valve chest, in which slides the double piston rod, *A*, and the space above the piston, *C*. Consequently, steam is admitted above this piston, which, being of larger diameter than the piston below it, forces it and the valve rod downward, thus opening the steam port into the bottom of the cylinder, and so beginning the up-stroke of the piston. The up-stroke continues until the nut above piston, *G*, closes valve, *D*, thus cutting off steam from the space

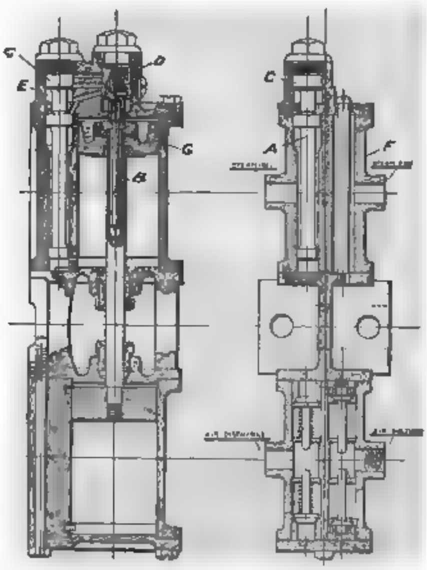



Fig. 380.—Sectional View of the Valve Motion and Mechanism of the "Victor" Auxiliary Steam Pumps.

above the piston, *C*, and again causing the plunger to rise. The position of the exhaust valves is such that they are covered by the piston valves on rod, when these are in position to open the inlets, and are opened again as soon as the inlets are closed, thus establishing communication with the exhaust chamber, *F*. The operation of the valves of the pump is obvious and requires no further description.

# CHAPTER FORTY-FOUR.

## LIQUID FUEL BURNERS AND REGULATORS.

**Of Liquid Fuels in General.**—All light steam carriages, and many heavier vehicles as well, use liquid fuel, oil or mineral spirit, to produce heat for their boilers. Such liquid fuel is not burned in liquid form, as is oil in an ordinary lamp, but is vaporized by heat, the vapor or gas thus produced being fed to the burner and ignited, in the same manner as ordinary coal gas used for light or heat in houses. It would be impracticable to carry gas in tanks on steam carriages, since the difficulty of storing and replenishing the supply would be greatly increased. By the use of liquid tuels a vast saving is made possible, both in space and weight, while their consumption in gaseous form is another element of economy.

**Advantages in Using Volatile Fuels.**—A prominent English authority on motor carriages gives the following five considerations of advantage in the use of liquid fuels:

1. Their combustion is complete, no heat being lost in the form of smoke or soot.

2. They produce no ashes or clinkers, which must be periodically cleaned out. Hence there is no loss of heat or drop in steam pressure, due either to this cause or to the renewal of coal.

3. The flues are never incrusted with soot, which involves the best conditions for use of heat.

4. The temperature of the escaping gases is lower than with a coal fire, since there is no need that the air required for combustion should force its way through a thick layer of burning fuel. Whence the uptake temperature is generally about 400°, Fahrenheit, instead of between 600° and 700°, as with the use of coal fire.

5. Since the fuel is burned in fine particles, in close contact with the oxygen of the air, only a small excess of air over that actually required for combustion is admitted to the burner. The opposite is the case with coal.

As may be readily surmised, the calorific value of liquid fuels is far greater than that of coal. It has been estimated that, taking the two weight for weight, petroleum oil has about twice the heat efficiency of coal. Since, therefore, equal weights of both varieties of fuel occupy about equal spaces, it follows naturally that petroleum products are far more economical and serviceable for use in vehicles of any description, or in boats and ships, where the considerations of weight and space occupied, in ratio to the power, are all-important.

The liquid fuels most commonly used are kerosene and gasoline, both being vaporized by the heat of the burner; a kindling flame from liquid gasoline or alcohol vapor, or a specially arranged detachable auxiliary vaporizer, or "torch," being used at the start, and until the vaporizing tubes are thoroughly heated. Kerosene is less suitable for steam carriage burners than is gasoline. A far higher temperature is required to vaporize it, and a larger evaporating surface. Furthermore, it requires large, bulky and complicated burners to consume its vapor, and very frequently produces an excessive amount of carbonaceous residuum, which necessitates periodical cleaning and considerable trouble in generating heat. Gasoline, on the other hand, being a highly distilled product of petroleum, is more readily vaporized than kerosene, requiring generally no greater temperature than may be obtained by passing the supply pipe up through one flue of the boiler and down through another. Such heating as this would have very small effect on kerosene. The burners used for gasoline are simpler and more readily regulated than those used for kerosene. They may also be made much lighter in comparison to their heating power and are less difficult to fire up at the start. All these points are distinctly advantageous, if not imperative, on a light steam carriage, intended for amateur engine drivers. On a heavy wagon, intended to be managed by skilled engineers, they are of less importance, and may be readily superseded by the more complicated devices for using the cheaper fuel.

**The Gasoline Burner.**—Very nearly the typical gasoline burner for steam carriages is shown in an accompanying figure. It consists of a flattened cylindrical chamber, pierced from head to head by a number of short tubes, each of which is expanded into the holes prepared for it and flanged over to make a secure joint,

somewhat after the manner of a well-made boiler flue attachment. These air tubes, as they are called, are open to the air at top and bottom, having no communication with the interior of the cylindrical chamber above referred to. The gasoline enters the chamber, from a nozzle at the end of the feed pipe and through a tube entering at one side of the cylinder and extending inward about two-thirds of the diameter. This tube is called the "mixing tube," and its function is to make a mixture of air and gasoline vapor

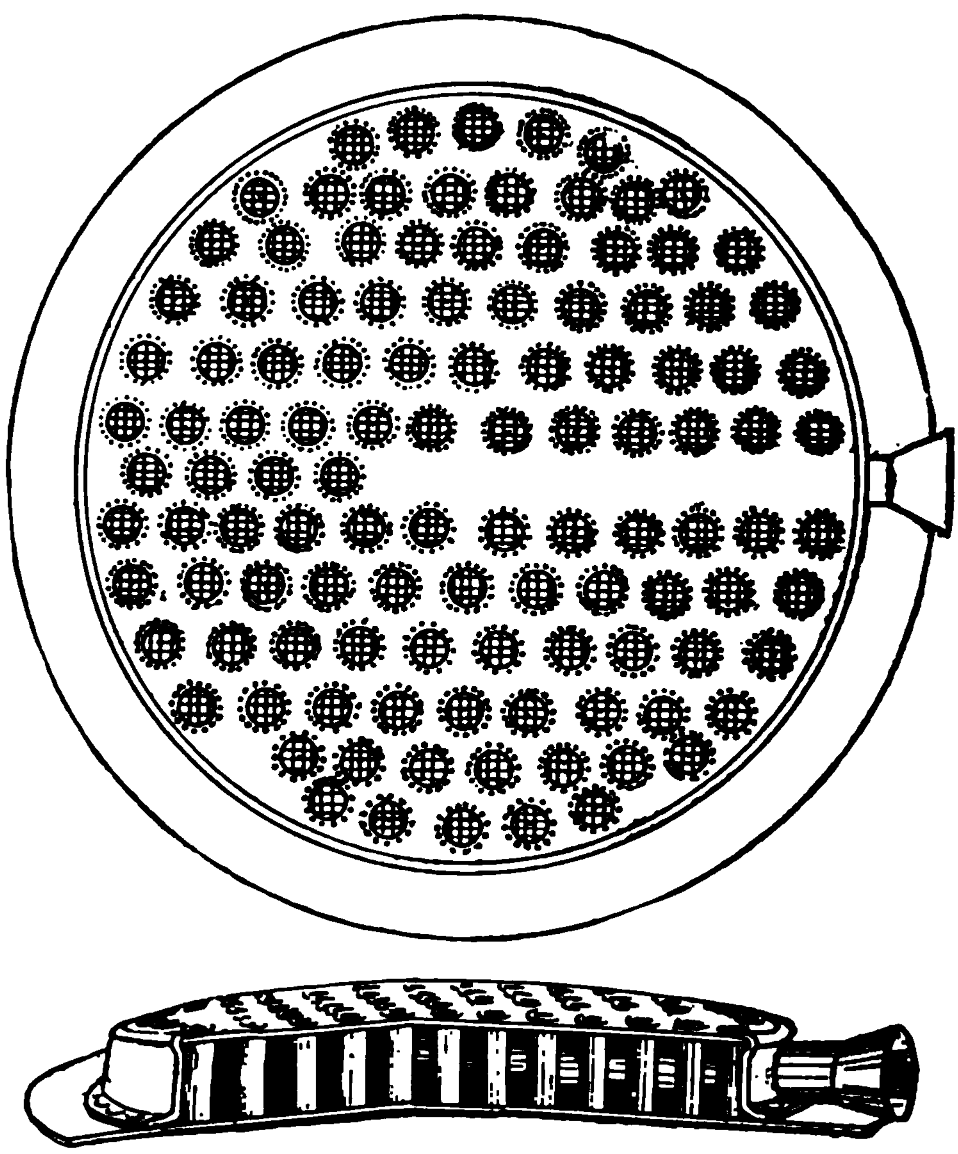


FIG. 361.—Plan and Part Section of a Typical Gasoline Burner for Steam Carriage Use.

that will burn readily in the atmosphere. Having entered the cylindrical chamber, there is no avenue of escape for the inflammable gas except through the circular series of pin-holes, which surround each one of the air tubes, as may be seen on the cut of the top of this burner. It is at these minute perforations that the gasoline gas is ignited, the combustion being rendered perfect by the air admitted through the air holes previously mentioned.

**The Storing and Feeding of Gasoline.**—The liquid gasoline for supplying gas to the burner of a steam carriage is carried in a tank, disposed generally to the front of the body, and sufficiently separated from the burner to avoid all dangers that might arise from leaks or overheating. Within this storage tank a good pressure of air is maintained—generally between 45 and 50 pounds to the square inch—from a separate air tank, supplied by a pump. This pressure is sufficient to force the liquid gasoline into the vaporizing tubes, when the supply cock is opened. After it has been vaporized the circulation continues, as controlled by the steam pressure diaphragm regulator, which operates a needle valve on the tube supplying the burner, the amount of gas and liquid gasoline moving between the supply tank and the burner being thus determined. If the fire is blown out in the draughts created by travel, the difficulty may be generally remedied by using higher air pressures in the tank. Some drivers have used as high as 100 pounds and over.

The pressure in the air tank is produced and maintained, either by a small hand pump, such as is used to inflate pneumatic tires—this method is used on several well-known American steam carriages—or else by some such specially designed pump, as is used on the Victor carriage, or some others described.

**The Automatic Fuel-Feed Regulator.**—The fuel-feed regulator, of which there are several serviceable forms, is one of the most necessary attachments of a steam carriage. Generally, it consists of a diaphragm, which, actuated by steam pressure from the boiler, automatically closes, or partly closes, a needle valve, thus regulating the amount of fuel fed to the burner. Several such apparatus are shown in section in **Figs. 362, 363.** There, as may be seen, the diaphragm is fixed across the tube leading from the steam space of the boiler. Against its inner side bears a solid head, or pressure cap, carrying a rod, at the farther end of which is a needle valve. The pressure cap is normally held against the diaphragm by a strong spring. When sufficient steam pressure bears upon the diaphragm, the spring is compressed, allowing the rod attached to the head to be pushed inward, thus regulating the needle valve, according to requirement. The instrument, thus formed, consists of two parts. The one is the pressure chamber containing the spring, whose pressure on the head is regu-

lated by an adjusting screw, through the shaft of which passes the valve rod. The other is the gasoline chamber, into which the fuel for the burner is admitted to the left of the point of the needle valve; its outlet being controlled, as shown, by two hand-wheel valves—one leading to the main burner through the mixing tube, the other being intended to let out a sufficient supply of gasoline to the starting device, which may be a detachable "torch," or auxiliary vaporizer, or some arrangement of drip cup and preliminary generating coil. This arrangement of the valves is shown in different cuts of burners and automatic regulators, being there sufficiently designated. Thus, as shown in the figures,

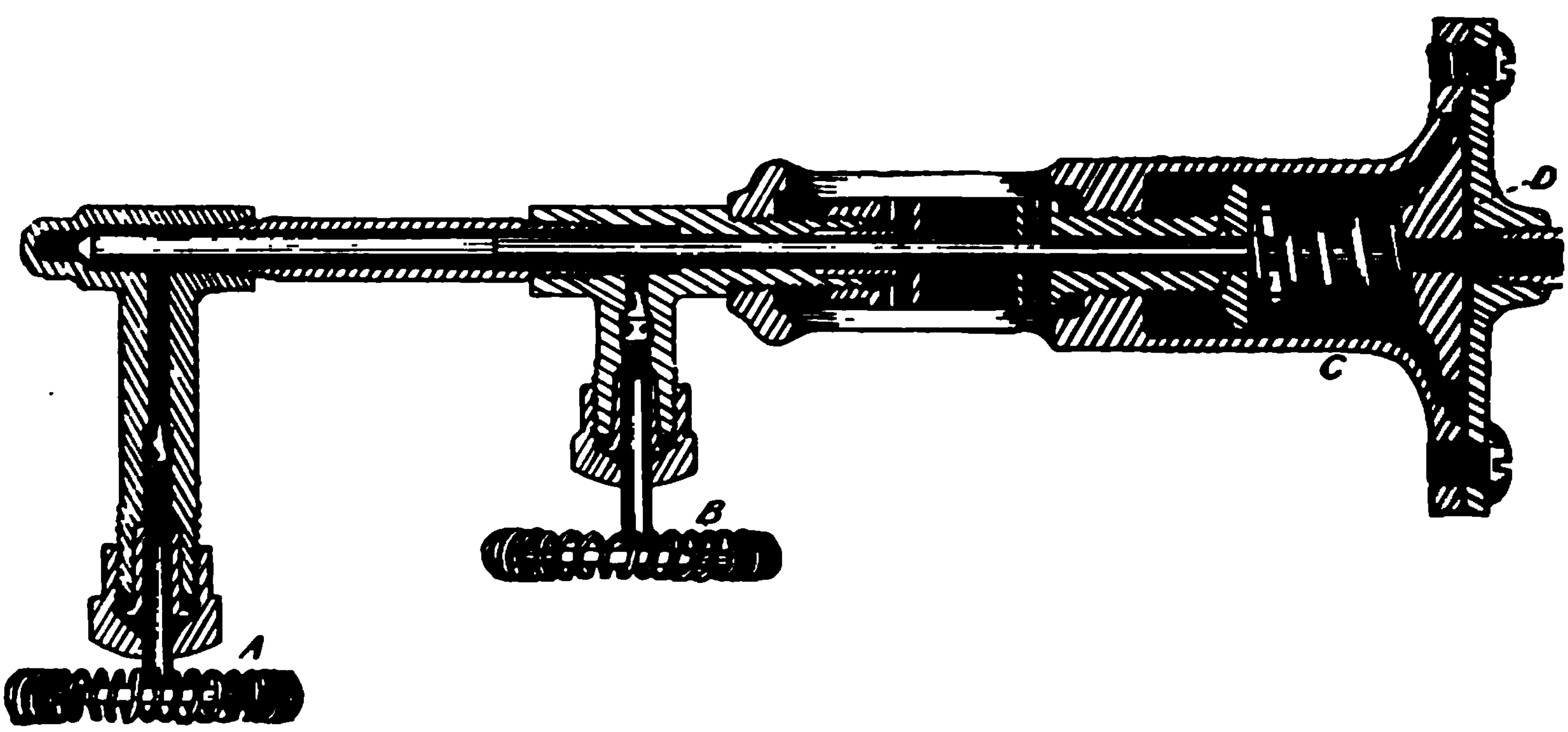



FIG. 312.—Fuel Feed Regulator of a Steam Carriage Burner, intended for Use with "Torch" Burner Kindler or Auxiliary Vaporizer. A is the hand wheel and needle valve regulating the feed to the main burner; B, the hand wheel and valve for operating the torch; C, the spring and header attached to the main valve rod; D, the diaphragm against which steam bears, regulating the main valve according to pressure. The liquid gasoline is admitted at a port on the left-hand extremity of the regulator tube, near the end of the needle valve on the main rod.

the valve rod, in entering the gasoline end of the regulator, passes through a stuffing box, so as to prevent all leakage at that end.

Of course, until there is sufficient heat generated to vaporize gasoline for the regular burner and generate steam pressure in the boiler, the automatic regulator cannot operate, as described, and the flow of gasoline to the starting burner or vaporizer is regulated solely by the hand valves.

Another form of regulator, shown in an accompanying cut, used on steam wagons, has the advantage of simplicity in this particular, doing away with both spring and stuffing box. The

diaphragm has concentric corrugations, and to its centre is attached a valve rod having longitudinal groovings to permit the fuel to enter the feed tube in such quantities as the pressure on the other face of the diaphragm will permit. Steam pressure, being thus brought to bear, tends to deform the diaphragm; hence compressing the valve rod and decreasing the rate and quantity of fuel feed. The fuel is supplied from the storage tank through the port into the lower chamber of the two formed by the diaphragm, as may be readily understood.

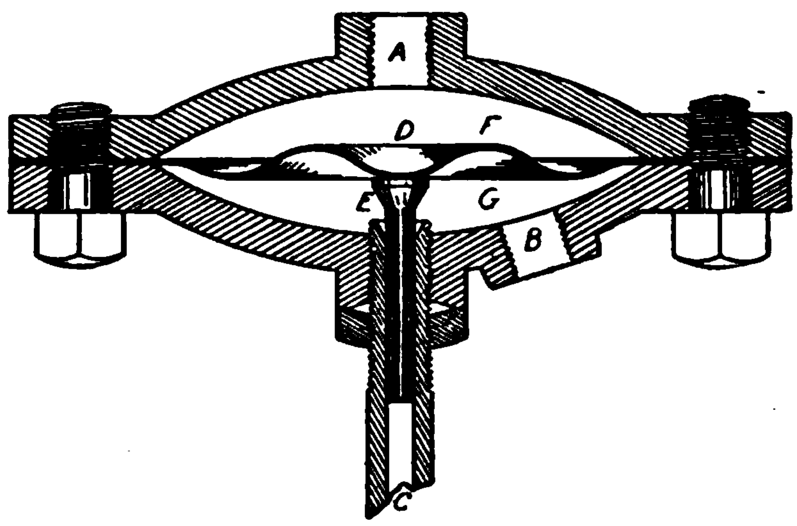



FIG. 363.—Gasoline Burner Regulator, operating with a corrugated diaphragm, like a steam gauge. A is the inlet for steam; B, the inlet for liquid gasoline; C, the port leading to the burner; D, the diaphragm; E, the head on the grooved rod of the valve; F, the steam chamber; G, the gasoline chamber.

**Constructional Points on Gasoline Burners.**—Several steam carriage burners are formed by riveting together a steel flattened cylindrical pressing and a plane disc, as shown in a former figure, inserting and expanding the draught tubes into suitably arranged perforations, as is done with the flues of boilers. Such a construction is apt to be faulty, however, owing to the fact that the steel plates tend to warp under the influence of heat, causing the draught tubes to leak, and the attachments to wear. The danger of these accidents has moved several inventors and manufacturers to design and produce burners formed with a cast top and steel plate base, or to cast both elements. By the use of castings warping is positively prevented, and leaking at the joints of the draught tubes is obviated.

One of the best-known burners of this construction is that widely known as the "Dayton," which possesses the additional feature of supplying gas for the burner flame through annular openings around each of the draught tubes, instead of using the

"pin-hole" design, already described. It is possible to construct with this feature, since the air tubes are cast in one piece with the head and base plates, being afterward reamed out, so as to make them uniform in size. In addition to this air opening, a counter-bore is sunk in the top plate of the burner, and a steel washer is fitted into it, leaving an annular opening for the passage of gas in the inside of the washer. The outside of the washer has a number of small openings in it, so that each air tube is surrounded by two concentric circles of flame. This construction affords a very large heating capacity, and also, as is claimed, prevents the top of the burner from cracking, also less liability


FIG. 364.—The Dayton Burner, showing the Starter Box and Regulator in Position.

of chocking with rust, dust or carbonized particles, which is a frequent source of annoyance with "pin-hole" burners.

An interesting variation on the common type of steam carriage burner is presented in the device used on the Whitney carriage. This burner is made with the usual top and base plates, the air tubes being inserted and flanged over, as already described. Instead of the usual slits or punctures for the gas to pass through, each tube is perforated on each 90° of its circumference; thus making communication to the interior of the gas chamber within the flattened cylinder. A second tube is then inserted within the first, fitting closely, except for a slightly diminished circumference at about the level of the perforations just mentioned. The

gas from the mixing chamber, entering these perforations, passes between the two tubes, and, mixing at the top of the tube with the air drawn through the draught tube, produces a very hot flame, as in the ordinary type of Bunsen gas burner. A similar effect is gained with several types of burner using a number of straight perforated tubes with air spaces between, thus ensuring plenty of air for combustion from both sides of the flame.

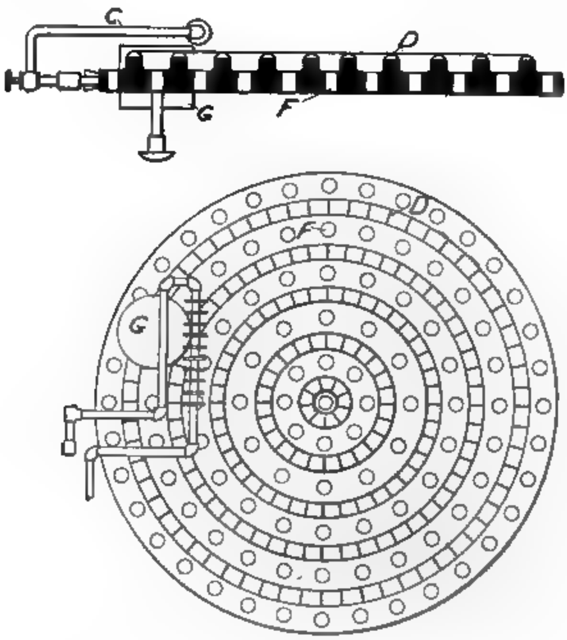



FIG. 365.—Plan and Sectional Elevation of the White Burner.

**The White Gasoline Burner.**—The burner used on the White carriage is also an interesting departure from the common types. As shown in the plan and sectional sketches, it consists of an upper, or face, plate of cast iron, having concentric corrugations, between which are the draught tubes, connecting the top and base plates, as in other burners. Instead, however, of the usual pin-holes or slits around the openings of the draught tubes, there are concentric rows of radially disposed slits across the raised corrugations on the face of the upper plate. The sketch shows

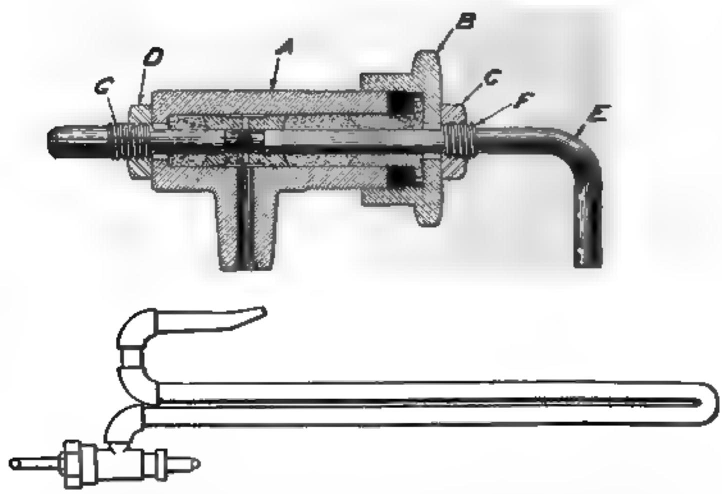



FIG. 366.—Usual pattern of "torch" head and starting "torch," used on several American steam carriages. The head parts are lettered as follows: A, body of head; B, threaded cap; C and D, nuts working on screws, F and G, on rod, E. Screw, G, gives attachment to the collar on the valve stem, as shown at B, in the succeeding figure.

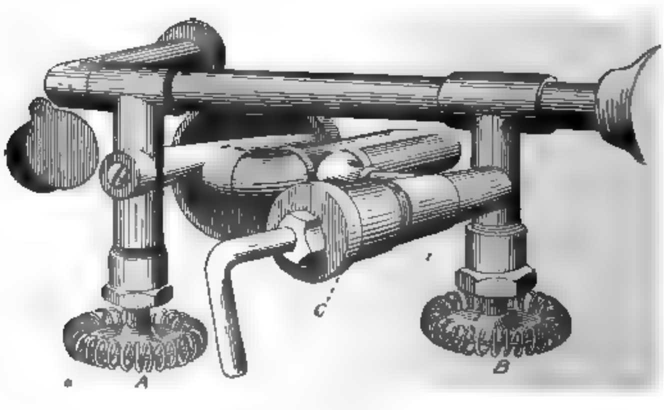



FIG. 367.—Showing the torch in position. By reference to Fig 366, it may be readily understood that the head of the torch, C, is attached to a nipple on B by screw, G; the bent tube being thrust through a port in the burner casing so as to come directly over the fire, the nozzle entering the mixing tube by the side of the nozzle on the main valve, A.

these in larger number than on the burner in actual use, which, being about 14 inches in diameter, has the slits arranged at intervals of about ½ inch.

Obvious constructional and practical advantages inhere in this design, since: (*a*) The draught tubes, being separated from the flame, cannot be loosened by the heat. (*b*) Being arranged to either side of each circle of flame, sufficient oxygen is supplied to produce perfect combustion. (*c*) The construction is such that there is no danger of warping or deformation under heat.

The automatic thermostatic regulator, described above, is used with this burner. The incoming gasoline supply goes to the preliminary vaporizer, *C*, over the pilot burner, *G*, thence through the vaporizing tubes, and through the regulator, and into the mixing chamber, whence it emerges through the fire slits, *D, D*.

**Methods of Starting the Fire: The "Torch."**—There are several methods of starting the fire in gasoline carriage burners, each having been devised as an improvement in way of simplicity and ease of operation.

The most familiar method of starting the fire is by the use of a removable auxiliary vaporizer, or "torch," such as is used on the "Mobile," and several other well-known steam carriages. It consists, briefly, of a continuous iron tube bent double at the centre, as shown, and having a cock and screw head at one extreme and a tapering nozzle at the other. This instrument is held in the fire of an ordinary stove, or over a fire kindled with cotton waste saturated with gasoline, until it reaches a temperature usually described as a "sizzling heat," which is to say the point at which any moisture applied to its surface will occasion the familiar "sizzle," noted when water is dropped on a stove lid. It is a heat just below the point where iron begins to redden. Some authorities advise that the "torch" be heated to a "dull red," as that will give a better temperature, when it is inserted in the burner.

The "torch," having been heated, its double bent tube is inserted in an aperture in the burner casing, designed to receive it, the screw and valve end being attached at an aperture controlled by the pin valve and hand-wheel, *B*, in the sectional cut of the automatic regulator, and its nozzle being inserted in the same aperture as is penetrated by the nozzle controlled by the pin valve and hand-wheel, *A*, in the same figure. This done, the hand-

wheel, *B*, is turned, so as to open the needle valve at the end of its stem, as far as is required; thus admitting liquid gasoline into the double bent tube of the torch through the screw and valve attachment. The result is that, passing through the heated tube, it is vaporized, and the burner is ignited by a match or paper lamp-lighter thrust through an aperture prepared for that purpose.

**An Auxiliary Coil Starting Device.**—The starter used with the "Dayton" burner, already described, is shown on page 532, Fig. 364, There, as may be seen, a small box, called a "starter box," is attached at one side of the burner It contains a short coil of tubing, into which liquid gasoline may be admitted by opening the valve marked "starting valve." A few drops of liquid gasoline are then allowed to drip into the "starting cup," beneath the coil, and this, set on fire, will speedily generate sufficient gas to light the pilot burner, from which, in turn, the main burner may be kindled as soon as the vaporizing tubes are sufficiently heated. As soon as this point is reached the needle valve to the main burner, shown at the right hand of the starter box, is opened, admitting gas through the nozzle into the mixing tube. By closing this valve, the main fire may be shut off, as desired, although the pilot light continues burning, until extinguished by shutting off its supply of gas, which is never modified in any way, being out of reach of the automatic regulator controlling the fuel feed to the main burner.

# CHAPTER FORTY-FIVE.

## SIMPLE STEAM CARRIAGE ENGINES.

**American Steam Carriage Engines.**—In the particular construction of steam engines for use on motor road carriages there has been almost as much variety of design as in the other branches we have already noticed. We may say, however, that the typical engine for steam carriages, as constructed in America, is the two-cylinder, double-acting engine, reversible with the Stephenson link motion. The high perfection to which these engines have been brought in America enables the construction

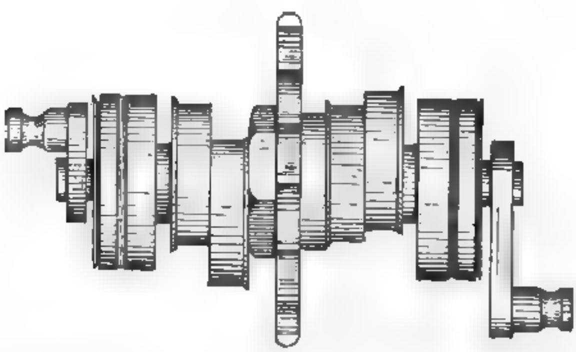


FIG. 368.—Crank Shaft of the "Locomobile" Steam Carriage, showing the cranks at both ends, the ball bearings and eccentrics, and the sprocket at the centre. Most steam carriage engines have similarly arranged crank shafts, although with several makes the entire mechanism is turned from one solid casting.

of very small motors, and the production of a high percentage of power. As a usual thing such engines work simple, but several excellent types of the American steam carriage, such as the McKay and the Stearns, are equipped with compound engines, which, however, may be run simple when the extra power is required, as, for instance, when ascending steep grades, or running through unusually heavy roads. A few steam carriages, notably the Reading carriage, are also equipped with single-acting multiple cylinder engines, which combine peculiarly ingenious devices for effecting reversal and controlling the valve

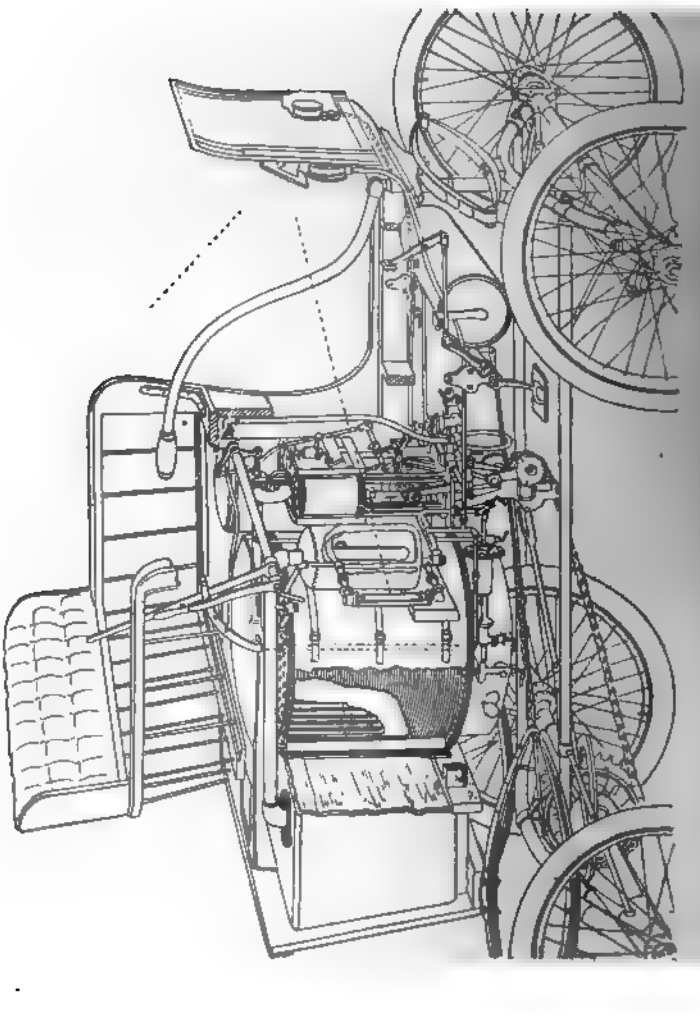


Fig. 387.—Part sectional view of the "Locomobile" Steam Carriage, showing machinery and parts in position.

gear. Single-acting steam engines, with from two to six cylinders, have also been brought to high perfection in Europe, being most familiar in the Gardner-Serpollet carriages.

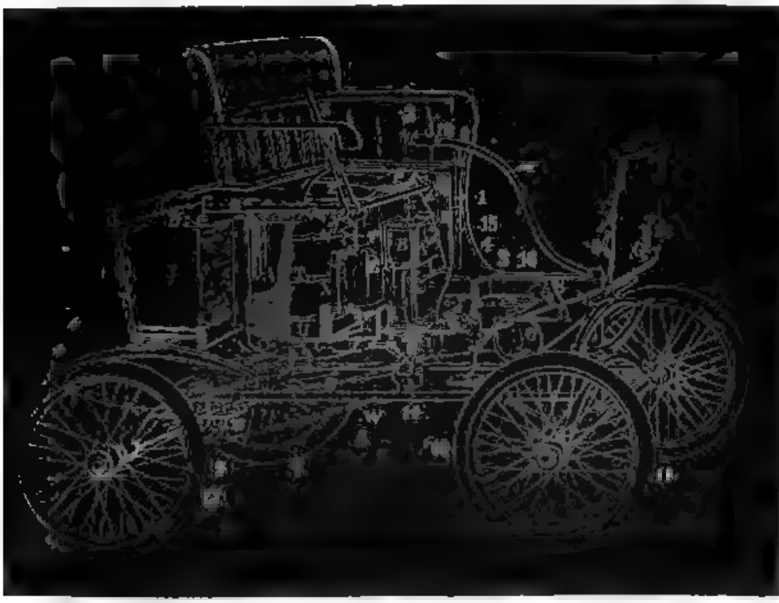


FIG. 370.—Diagram of the "Locomobile" Steam Carriage, showing parts in position. A is the boiler shell of copper; *a*, the winding of steel piano wire; B, the double cylinder engine; C, the adjustable strut, or distance rod, D, the compensating gear; E, pipe leading from engine to muffler, F, for exhaust steam; G, pipe leading from muffler to vent at H; I, the water supply tank; J, feed pump operated from the engine cross-head, K, cock in front of check valve on water supply pipe, for cutting off the supply from the tank, L, pipe leading from pump to the by-pass, M; N, lever for operating the by-pass, O, fuel supply tank, P, reserve air tank; Q, the dashboard, R, the air-pressure gauge, S, pipe leading from fuel tank to burner, through which gasoline is passed under air pressure; T, metal straps holding the lagging, U, around the boiler, A, V, the diaphragm fuel feed regulator, explained in connection with Fig 207; W, pipe leading steam from boiler to diaphragm of the regulator, X, the water glass; Y, the mirror for reflecting the water glass, Z, starting lever. Other parts are: The crank arm on Z acting on the lever (1), the reversing lever (2), crank arms on the reversing lever (8 and 4); the pop safety valve set at 240 pounds (5); the steam pressure gauge (6); fuel valve to main burner (7); foot pedal (8) operating band brake (9); wire wheel spokes (10); pneumatic tire (11); steering handle (12); sprocket on rear axle (18); blow-off valve (14); oil feed cup on engine cylinders (15), pipe from air tank to fuel tank (16).

**The "Locomobile" Carriage and Its Engine.**—One of the most efficient among the American double-acting simple engines is that operating the "Locomobile" steam carriage, which has two cylinders of 2½ inches diameter by 4-inch stroke, and a total

output of 4 to 5 horse-power, at between 300 and 400 revolutions per minute. It is equipped with the Stephenson link motion and "D" slide valves, and operates the boiler pump from the crosshead. The crank shaft of this engine, shown in the

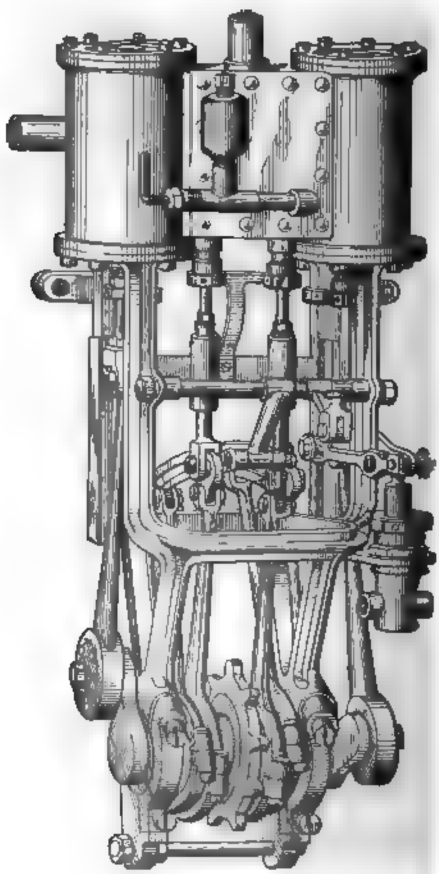


FIG. 371—The "Locomobile" Steam Carriage Engine.

accompanying drawing, carries the sprocket at the centre, the eccentric drums on either side, and runs in enclosed ball races, with the cranks at either extremity. The cranks are fixed at 90 degrees. As seen from the accompanying figure of the en-

gine, the cylinder and driving gear are hung on a heavy cast frame. This frame is bolted to a wooden crosspiece rigidly attached to the body frame of the carriage.

To the base of the frame is attached an adjustable strut, or distance rod, by which its relative position, as regards the rear axle, may be varied by a right-and-left threaded nut, or turnbuckle. By this device the slack of the chain may be taken up, and, to allow for the slight variation, thus necessitated, the steam pipe connection to the top of the steam chest is by a U-shaped pipe provided with "expansion joints."

The boiler used in this carriage has already been described

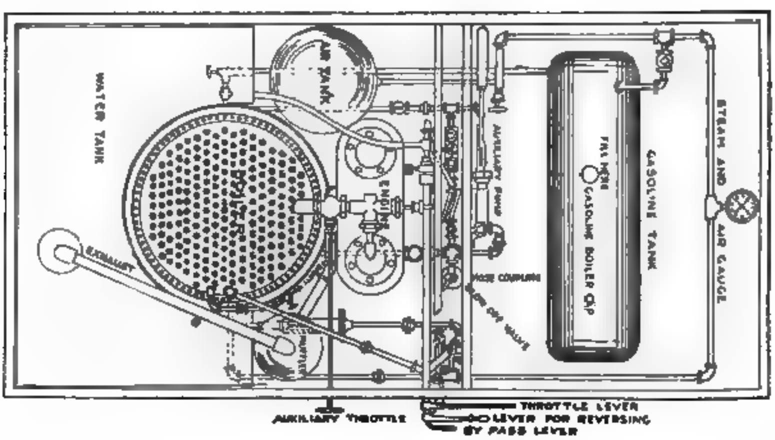



FIG. 372.—Plan Arrangement of the "Locomobile" Steam Carriage, showing position of the parts indicated in Fig. 245.

in connection with Fig. 370. It is supplied by a small plunger pump operated from the crosshead of the engine, drawing its water from the tank shown at the rear and either side of the boiler. On the runabout carriages of this make the water tank has a capacity of fifteen gallons. The water may be cut off by closing the cock, shown at $K$ in the lettered diagram of this carriage, or may be returned to the tank by opening the by-pass valve, $M$, by the lever, $N$, at the driver's right hand. Up to the present time the manufacturers of this carriage have avoided the use of most automatic devices, other than the fuel regulator, as already described.

# CHAPTER FORTY-SIX.

## SINGLE-ACTING STEAM CARRIAGE ENGINES.

**The Serpollet Single-Acting Engines.**—In the effort to simplify, as far as possible, the construction and operation of steam vehicle motors, intended for use on light carriages, several inventors have contrived excellent types of single-acting engines. Among the advantages to be derived from the use of this type of motor, we may mention dispensing with the stuffing-box and several other constructions, which involves constant danger of wear and difficulty of repair. Among the best known single-acting steam engines may be mentioned those designed by Leon Serpollet, and used on the steam carriages manufactured by his firm. As constructed by him, the single-acting steam engine

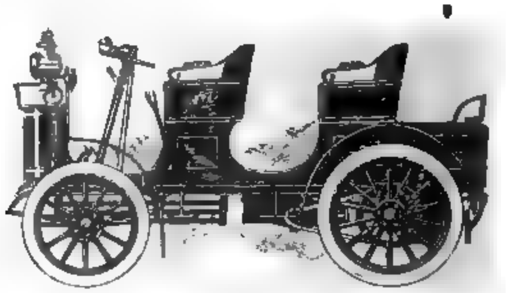


FIG. 873.—Gardner-Serpollet Steam Carriage built for King Edward VII. This carriage fairly represents the designs of Serpollet.

very much resembles some types of gasoline motors used on heavy vehicles, both as regards the cylinder and piston and operation of the valves. In an accompanying figure is shown an elevation, partly in section, of one of his horizontal double opposed cylinder engines. As may be seen there, the cylinders are open at the forward end, toward the crank space, in a manner very similar to that used on gasoline motors of the same pattern. The piston is of the trunk type, consisting of a somewhat elongated hollow cylinder, with the crank rod pivoted on the gudgeon pin somewhat less than midway in its length. The

valves in this engine are of the familiar mushroom or poppet type, and are opened by a push rod positively operated from a cam shaft. This shaft is operated by a spur-wheel, which meshes with another spur of the same diameter, mounted on the crank-shaft, so that the two turn in even rotation. The exhaust valves are of precisely similar construction and are also positively operated from the same cam-shaft.

Such an engine as this has been constructed with from two to six cylinders, and as may be understood, gives about the same

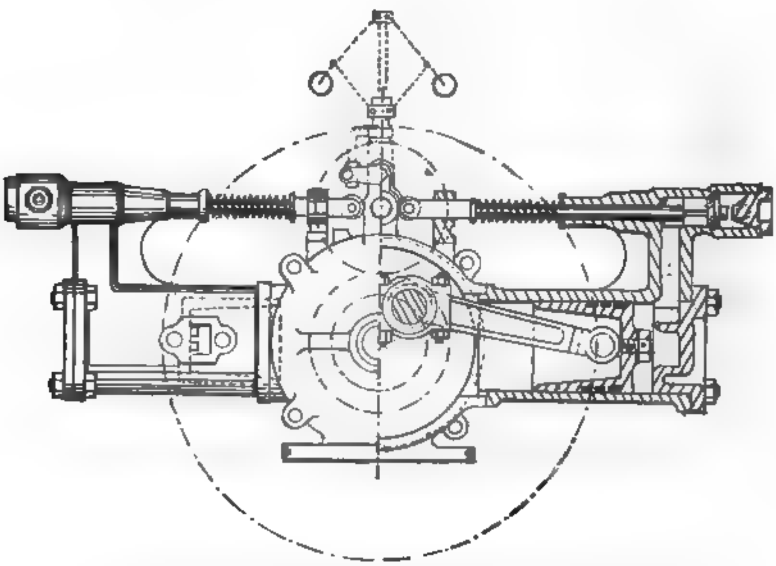


FIG. 874.—One Model of Serpollet Single-acting Two-cylinder Engine. As may be seen, this engine, with cam-actuated poppet valves, centrifugal governor for regulating the cam movement, and large fly wheel, closely resembles gas engines of the double-opposed cylinder type.

power effect as an engine of the ordinary design and same proportions of stroke, having from one to three cylinders. The cylinders operate on one plane, and are not offset, as in many opposed-cylinder gasoline motors, the danger of interference of the crank rods being prevented by constructing each of them to embrace only about one-third the circumference of the crank-pin, thus permitting a sufficient play to enable them to adapt their motion to the full dip of the crank. The crank ends of these rods are held in place by clamp brasses at either side. In

a diagonally arranged motor of the same description, the same end of non-interference is attained by forking the crank end of one of the crank-rods, and constructing the other single, so that the former may work over the latter on the crank-pin. As may be understood from the fact that the steam and exhaust valves are positively operated by a series of cams on a shaft, so that when the steam valve of one is open, its exhaust is closed, involving that the steam valve of the opposite cylinder is closed and its exhaust open. In order therefore to reverse the engine. it is necessary only to slide the row of cams on the square camshaft that carries them, so as to shift the positions and operation of the valves on the two cylinders.

All the Serpollet carriage engines of this description are supplied by the Serpollet flash generator, already described, the fuel and water being fed and regulated by a system of pumps and valves, already described. For driving an ordinary road carriage, seating two passengers, a two-cylinder motor is used, with a stroke and diameter each equal to about 2.55 inches, giving, with 700 revolutions a minute and a mean effective pressure of about 75 pounds, an approximate rating of 3 horse-power.

## CHAPTER FORTY-SEVEN.

### COMPOUND STEAM ENGINES.

**Compound Steam Engines for Light Carriages.**—Although many of the earliest types of the American steam carriage still use simple engines, several of the most excellent of the later patterns have adopted compound engines. The principal objection made by many authorities to the use of compound engines on steam road carriages of light weight is that with cylinders of average dimensions, working power of between 150 and 200 pounds, in the high pressure cylinder, and a cut-off generally between ½ and ¾ stroke, which has been found most economical under ordinary conditions, the low pressure cylinder would be doing little or no work, the whole strain of operation coming on the former, which would practically be working against a vacuum. On the other hand, with the final pressure of between 35 and 40 pounds, and the port clearances necessarily amounting to between 20 and 30 per cent., there is a considerable waste of steam, as well as excessive condensation. A well-known manufacturer of steam carriage engines states, that in order to obtain effective work from both cylinders of a compound engine, the high pressure cylinder must be made about one-half the size of the cylinder used in the simple engine. Then, he asserts, the mean pressure will range from 75 to 100 pounds in the usual running, with cut-off at ¾ stroke and the diameters of the two cylinders in ratio of 1 to 3, and the low pressure cylinder will do its share of the work, with the desired economy of power. The difficulty claimed with this arrangement is, that the total reserve power will then be only about one-half that of the simple engine; unless boiler steam can be admitted to both cylinders at any desired time while running, as well as in starting, and the back-pressure be eliminated by exhausting from both to atmosphere.

Another objection is that the efficient compound engines used in stationary power plants, on ships, and, to a certain extent in railroad locomotives, are operating constantly against a practically fixed load, which is not the case in steam carriage work.

But this is not of such vital importance, since the average run of compound engines, designed for light road carriage use, may be run simple, whenever it is so desired, and the power may be varied with any well-made simple engine by shifting the point of cut-off. Thus, as is admitted by most experienced steam-carriage drivers, the throttle valve must be very constantly manipulated, in order to maintain anything like uniform speed on ordinary roads, whose surface conditions are ever changing. One important consideration, however, is that a compound engine. with two cylinders of different dimensions, involves considerable vibration, and consequent strain on the parts, such as is not experienced with a simple engine, whose cylinders are uniform as to size and power-output. Thus, when running compound, the small cylinder is exerting a power somewhat in excess of the larger one, and, when both are running with live steam, the larger one is powered two or three times higher than the smaller. Such an objection undoubtedly holds good for a given type of engine, but with the better designed American road carriages, equipped with compound engines, the vibration seems hardly more noticeable than with the easy-moving simple engine.

**The Stearns Compound Engine.**—The compound engine used on the Stearns steam carriage is one of the most typical and efficient of its class. The high pressure cylinder is 2½ inches in diameter, by 3½ inch stroke, and the low pressure cylinder 3 inches in diameter, by 3½ inch stroke. As is claimed, each develops 2¾ horse-power when running compound, and about double that when running simple. As shown in the accompanying diagram, it is built on the usual plan of the double-cylinder steam carriage engine, each cylinder being controlled by piston valves of the usual construction. The valve chest also contains inserts or liners, which increase the accuracy of the parts and admit of ready adjustment when the old liners are worn by use. Between the two valve chests and in connection with both, is the controller valve chamber, which also contains a piston valve, similar to that used in connection with the cylinders, except that it is larger in diameter and has double connections. The position of this control valve may be altered by a lever coming to the hand of the driver, so that at any time the operation of the engine may be shifted from sim-

ple to compound or from compound to simple. This control valve is bored from end to end, and has the usual angular recess on its outer surface, besides the internal port extending clear around the top, bringing into connection various passages leading from the control valve chest to the high and the low pressure valve chests and their exhaust ports. As shown in the illustration, the control valve stands at a point just above the ports which cut off the steam from the steam chests. Were it lowered, so that its top would be even with the bottom port on the high pressure cylinder side, the engine would run com-

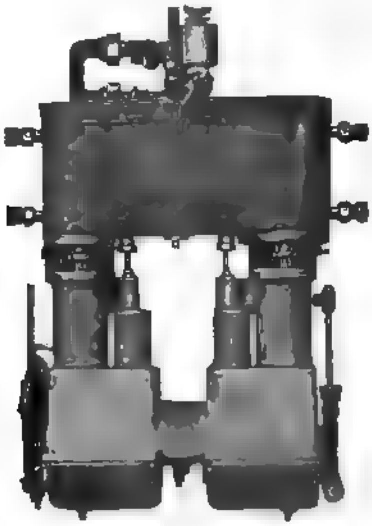


FIG. 3 5.—Compound Engine of the Stearns Steam Carriage.

pound. In this position, therefore, the live steam from the boiler passes from the control valve chest through the port just cleared by the control valve, to the high pressure steam chest, being then distributed by the high pressure valve, as it alternates between the two ends of the cylinder. The high pressure valve being shown in a position where the lower end of the high pressure cylinder exhausts, the path of the steam leaving this end of the cylinder may be easily followed to the steam valve, through the exhaust passage, and the high pressure valve through the passage leading to the control valve chest. Thence, through the

internal port of the control valve, and through another passage leading to the low pressure valve chest, it is distributed alternately to both ends of the low pressure cylinder. As the high pressure piston is shown at one-half stroke, and as the two cranks are

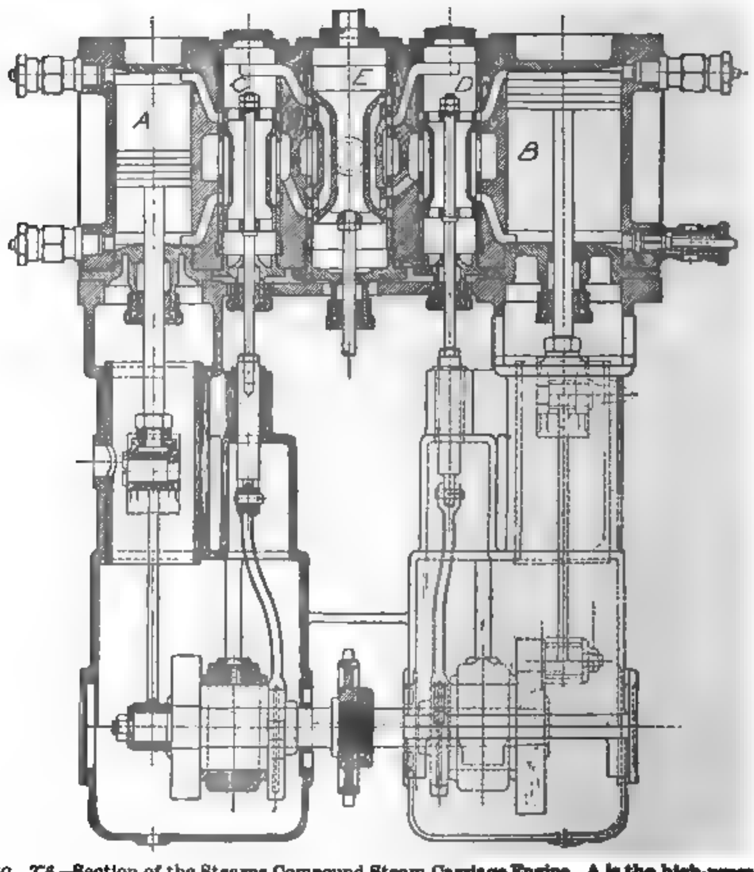



FIG. 376.—Section of the Stearns Compound Steam Carriage Engine. A is the high-pressure cylinder; B, the low-pressure cylinder; C and D, the steam valves operated by single eccentrics. E, the central control valve and chamber.

set at 90 degrees, the low pressure piston is in its extreme inner position, and the lower end of the cylinder is just beginning to exhaust. The steam exhausted from the low pressure cylinder flows through the port to the exhaust chamber surrounding the

low pressure valve, and from there through the passage to the exhaust chamber surrounding the control valve, whence it is led to atmosphere.

If the control valve be raised until the passage shown in the drawing, as connecting the exhaust port of the high pressure cylinder with the internal port of the control valve, be uncovered, the operations of the exhaust and admission ports are reversed and the engine runs in the reverse direction. When the control valve is shifted until it uncovers the passage shown in the drawing, as connecting its internal port with the low pressure valve chest, live steam from the boiler will flow to both valve chests, and the engine will then work simple, thus providing increased power that may be required in an emergency, as when ascending a steep incline or passing over an unusually rough road. Further, by slightly varying the position of the control valve, the steam may also be throttled by this manner of working the engine. The exhaust ports of both high and low pressure cylinders being then in communication with the central exhaust port, both will, therefore, exhaust to atmosphere. As shown in practice, these simple acts of shifting the control valve, may be readily and rapidly acquired, thus enabling the operator to economize both fuel and water by regulating the power output to the requirements of travel. Its practical operation also demonstrates, when running simple, that the average American steam carriage is somewhat over-powered for the requirements of good roads and average speed, and that a large percentage of the steam, ordinarily wasted, may be used for effective work.

**The Thornycroft Road Wagon and Compound Engine.**—The practice of using compound engines on motor road carriages has been much more frequently adopted on heavy wagons and lorries than on light pleasure carriages. One of the best known makes of motor road wagons using compound engines is the Thornycroft, several parts of which have already been described. The engine used on the two and four ton wagons, manufactured under the Thornycroft patents in England and America, is a two-cylinder horizontal compound engine, having a 4 inch diameter for the high pressure cylinder and a 7 inch diameter for the low pressure, and a stroke of 5 inches. The steam valves are of the balanced cylindrical type and are operated by single

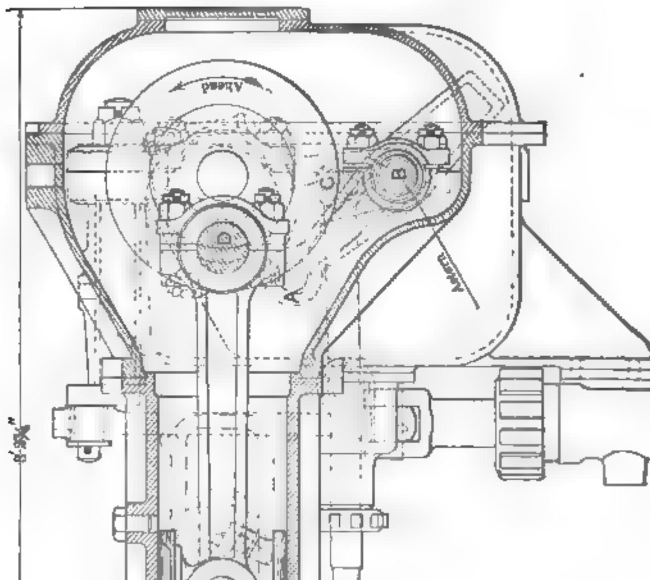


Fig. 277.—Sectional View of the Thornycroft Compound Steam Engine.

eccentric gear from the crank shaft. As shown in the sectional drawing of this engine, the eccentric carries an arm, *C*, which is connected to the valve rod by a link bar. It is also connected to the swinging link, *A B*, by which reversal may be effected. When this swinging link is in the position shown in the drawing, the wagon moves straight ahead; when it is brought downward, to the position marked "astern," the direction is reversed. The intermediate point, of course, has no effect on the movement of the valve. This device furnishes a simple and ready method of controlling the engine, and has the advantage of being less complicated than the ordinary link motion. An engine of the dimensions specified above can develop 20 brake horse-power at 440

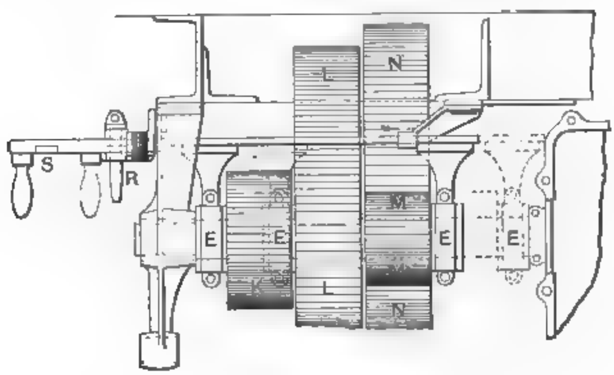



FIG. 378.—Change Speed Gear used on the Thornycroft Steam Wagon.

revolutions and 35 brake horse-power at 770 revolutions, when the low speed gear is in use. This is an exceptionally high rating for an engine of this size; measuring only $3\frac{1}{4}$x$2\frac{1}{2}$x$1\frac{1}{2}$ feet, and weighing less than 500 pounds.

Contrary to the usual practice with steam road wagons, both light and heavy, the Thornycroft wagon has a system of change speed gears, somewhat on the pattern of those used in connection with gasoline motors. As shown in an accompanying figure, these gears, mounted on a counter-shaft, may be changed by shifting in the width of the wagon by means of a lever, *S*. When this lever is in the position indicated, the low speed gears, *M* and *N*, are meshed. When, however, it is moved to the right, as indicated by the dotted lines, the bearings, *E* and *E*, are also shifted as shown, bringing the gears, *K* and *L*, into engagement.

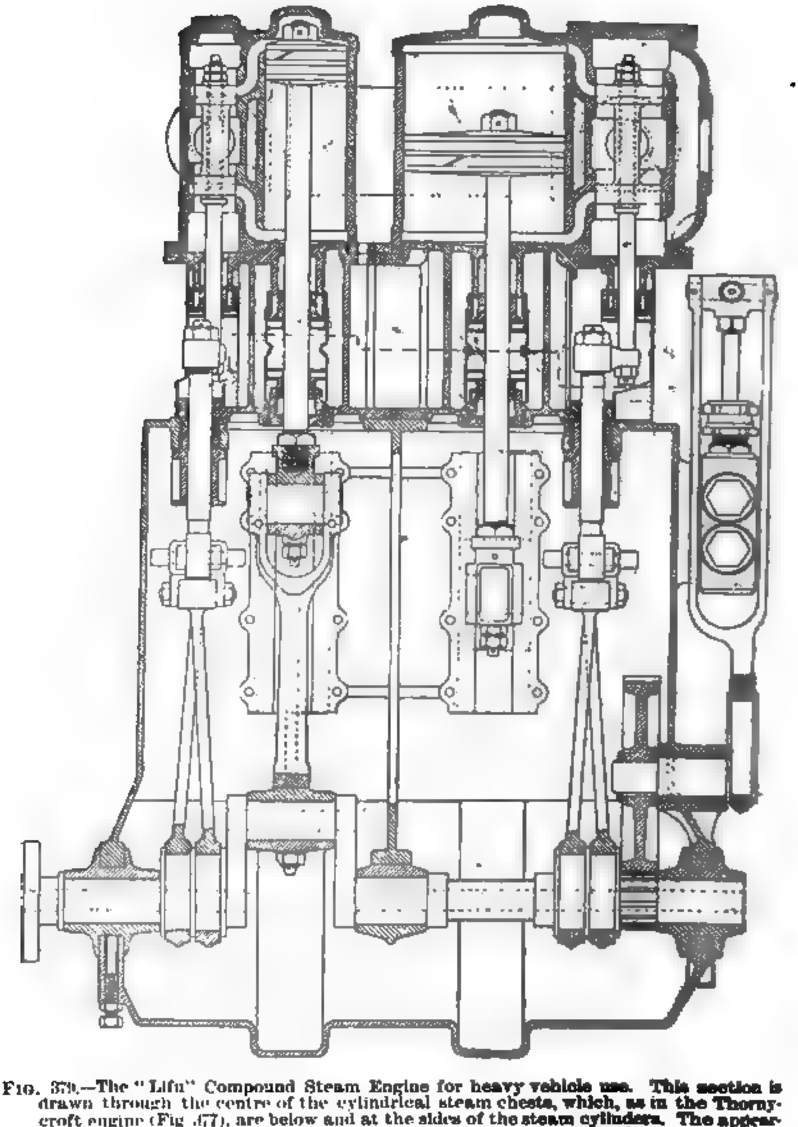


FIG. 379.—The "Lifu" Compound Steam Engine for heavy vehicle use. This section is drawn through the centre of the cylindrical steam chests, which, as in the Thornycroft engine (Fig. 377), are below and at the sides of the steam cylinders. The appearance of eccentricity in the attachment of the piston-rods may thus be understood.

This gives the high speed forward. The drive is through spur gears, as shown in Fig. 33, and explained on pages 38 and 40. The wheels turn loose on the axles, as in horse wagons, being driven through leaf springs secured to rotating axle sleeves and bearing against lugs on the felloes. This arrangement affords a very flexible connection and has high tractive efficiency. It is an improved form of the Hancock and Gurney drive wheels, as described and pictured in Chapter One.

**The "Lifu" Compound Steam Engine.**—The compound steam engine used on the "Lifu" steam wagons is shown in section in an accompanying figure. It is of the cross-compound horizontal type, with reversing links, having cylinders of 3 inch and 6 inch diameters respectively, and a 5 inch stroke. The steam inlet of both cylinders is controlled by simple balanced piston valves, and as indicated in the drawing, the valve boxes are placed somewhat below the general level of the engine. When running compound the steam is exhausted from the high pressure cylinder into a receiver tube, which, as shown by dotted lines in the drawing, connects the two cylinders and their valve boxes from below. There is also an auxiliary valve as shown at the right hand of the low-pressure cylinder, by which live steam from the boiler may be admitted direct to the low-pressure cylinder, thus permitting both to run simple whenever occasion demands.

Among the special features of this engine may be mentioned a second pair of gland boxes run between the forward cylinder head and the guide bars, in order to prevent all leakage of condensed steam into the crank case, which is enclosed so as to allow the moving parts to run in oil. The main feed pump is worked from the crank-shaft, being geared direct to a single eccentric, which works on a small secondary shaft operated from the main shaft by spur-wheels. Attached to the strap of this single eccentric is a forked connecting rod which works on a crosshead attached to the rear of the pump. By this arrangement it is possible to reduce the speed of the pump, since the ratio of the two meshed spur-wheels is about 1 to 6. In addition to this pump, there is also an independent steam pump for use in case of emergency.

**The White Steam Engine and Carriage.**—The later models of the White steamer are built on the lines of gasoline touring cars, having the compound engine at the front of the body, under a bonnet and driving direct, by propeller shaft and bevel

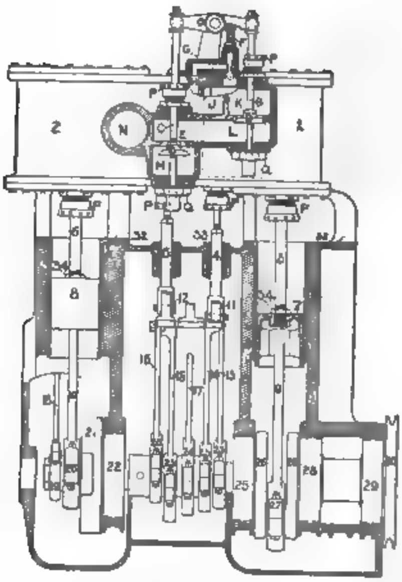


FIG. 380.

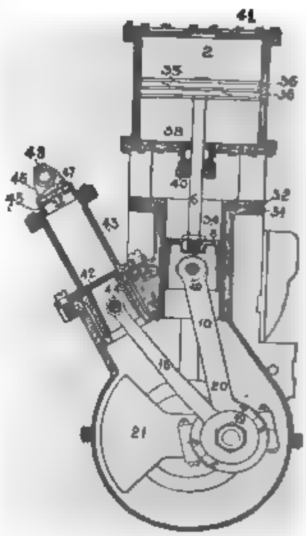


FIG. 381.

FIGS. 380 and 381.—Sectional Diagrams of the White Compound Steam Engine. The parts are: 1, high-pressure cylinder; 2, low-pressure cylinder; 3, h.p. piston rod; 4, h.p. valve stem; 5, l.p. valve stem; 6, l.p. piston rod; 7, h.p. crosshead; 8, l.p. crosshead; 9, h.p. connecting rod; 10, l.p. connecting rod; 11 and 12, valve links; 13, 14, 15, 16, valve eccentric rods; 17, water pump eccentric rod; 18, 19, air pump connecting rod and rod end; 20 and 27, connecting rod crank ends; 21 and 26, counter-weights; 22, 25, 28, 29, crank-shaft bearings; 23, valve eccentrics; 24, eccentric operating water pump; 30, belt wheel of oiler; 31, aluminum engine casing; 32, brass liners for crosshead guides; 33, valve stem bushings; 34, lock nut on crosshead; 35, l.p. piston; 36, piston rings; 37 and 41, cylinder heads; 38, stuffing box; 39 and 40, gland and cap; 42 and 43, air pump piston and cylinder; 44, wrist pin; 45, 46, 47, 48, cylinder cover, check cap, check valve and air delivery of air pump. The simpling valve mechanism lettered: A, steam valve from high to low pressure steam chest; B, exhaust valve from h.p. cylinder; C, h.p. exhaust valve from l.p. steam chest; D, poppet valves; E, lock nuts; F, spring holding valve, A; G, H, passage opened by valve, A; I, h.p. steam chest; J, wall between steam chests; K, h.p. exhaust to air; L, h.p. exhaust to l.p. steam chest; M, opening into l.p. steam chest; N, l.p. exhaust; O, rocking lever; P, stuffing boxes; Q, Q, simpling valve plugs.

gear connections to the rear axle. In starting the engine, pressure on a foot pedal causes both cylinders to receive "live steam" from the boiler. This operates the simpling device actuated through the rock shaft mounted on top of the engine.

From the engine the exhaust steam proceeds to the condenser at the front of the bonnet, then through the separator, where the cylinder oil is removed, to the tank. After condensation, the water is returned to the tank and is used over and over again, one filling of the tank serving for 150 miles.

Of the two pumps supplying water to the generator, one is sufficient for ordinary conditions. When a greater steam supply is desired, the closing of a hand-valve, projecting from the dash towards the steering wheel, puts the seccond pump into active operation. The method whereby the supply of water to the generator is automatically shut off when the pressure exceeds a certain fixed amount, is entirely independent of the method of varying the amount which can be supplied by this two pump arrangement.

An enclosed crank case protects the working parts from dust and permits splash lubrication. The valve motion is of Stephenson link type, centrally hung, and between the two pairs of valve eccentrics is a fifth eccentric which operates, through a rocking arm, the double-ended plunger of the feed pump and the condenser pump on the left side of the engine. Connected directly to the upper or feed pump is the diaphragm regulator, which governs the by-pass valve. When this valve is open the water passing through the pump returns by a short bent pipe directly back to the bottom of the pump, and so circulates continuously until the by-pass valve is closed.

The water pumps are operated from the engine shaft, so that, when running on the lower or emergency gear, water is fed faster to the generator, and steam is generated faster than under ordinary conditions.

Within the case containing the differential gear is a device whereby the speed ratio between the rear axle and the engine can be reduced from 1-to-3 to 1-to-7, or the gears may be entirely disengaged and the engine run free. The gears are in no sense change speed gears, but are for emergency only. All ordinary control is by means of the throttle mounted above the steering wheel.

## CHAPTER FORTY-EIGHT.

### GASOLINE MOTOR CYCLES.

**Requirements of a Motor Cycle.**—According to experience in the matter, a motor cycle must be propelled by an air-cooled motor, preferably of rather low speed and of somewhat higher power rating than is actually required for the load to be carried. The reasons for both conditions are readily discoverable, since, having dispensed with the water-cooling and circulating system for sake of lightness and compactness, it is desirable to avoid such causes of overheating as unusually high speeds, and such low power as would cause the engine to labor under ordinary loads. Some bicycles have been constructed for racing purposes, with an advertised speed of 60 miles per hour and over, several of them having been equipped with a motor guaranteed to develop six horse-power, a rating far in excess of demands for carrying one person over an even roadway. At best, such machines are bulky and heavy, out of all proportion to convenience of handling or for ordinary service. Even with some machines designed for ordinary road service, and having an extreme speed limit of more than 25 or 30 miles per hour, the motor used is guaranteed to develop 2, and even 3 horse-power at between 1,200 and 1,500 revolutions per minute—speeds seldom attempted.

**Regulating Attachments on Bicycles.**—The motor bicycles manufactured in America use jump spark ignition, almost without exception. Few of them also have any regulating devices other than levers for varying the time of the spark and the opening of the valves—thus modifying the speed—and a cut-out switch located conveniently on the handle bars, for the purpose of stopping the motor. Adjusting the mixture or varying the time of the spark are the typical means provided for changing the speed. It is obviously impracticable to include such change-speed gears as are used on heavy vehicles and even on some tricycles, since the rider would be quite unable to operate such with safety, certainty, and convenience.

One excellent make of American motor bicycle has dispensed with the spark advancing apparatus, and varies the speed solely by interrupting the sparking circuit. A published description of this machine sets forth the system, as follows: "This cycle will run at a speed of from 5 to 25 miles an hour at the rider's discretion, and is under perfect control all the time. The instant the switch plug is pressed down the power is off, and at the same instant the compression in the engine acts as a brake on the rear wheel, which with the application of the brake on the front wheel, brings the machine to a stop as quickly as is possible, without a sudden stop. The timing of the spark can always be maintained by the adjustment of the screw without removing any parts of the motor.

By the elimination of the advance spark mechanism this company claims that the machine has been much simplified. They claim they have demonstrated that a stationary spark is a perfect method, and the speed is regulated by the amount of gas fed to the engine. The rider controls his speed without removing his hands from the bars. A slight pressure of the thumb on the switch plug interrupts the electric current and shuts off the power instantly, a pressure of the index finger on the other end of the switch plug again completes the electric circuit and throws on the power. This enables him to increase or slacken his speed by pressing a button.

One of the things to be most avoided in motor bicycling is skidding, which is obviously much more dangerous than with foot propelled machines. A well-known English authority writes as follows on this point, illustrating the usefulness of certain constructions:

"It is generally known that an exhaust valve lifter is indispensable in this connection; but a very delicate carburetter which does not fail to give mild explosions, when the throttle is nearly closed, and which, in conjunction with mechanical valves, will keep the engine running 'dead slow,' is a useful safeguard against skidding. The next safeguard is a flexible drive. Advantage in this direction will be derived from having the flywheels much larger without being heavier. The jerks will be diminished and as it is the beginning of a slip that must be avoided, every trifle counts. Also, if these larger flywheels were to rotate in the opposite direction to the road wheels, then gyrostatic action would

assist the rider in keeping vertical instead of acting in the opposite sense, as they do now." Exactly how his "gyrostatic action" could be obtained our authority does not specify, although the principles laid down seem to possess some element of truth.

One or two of the earlier types of motor bicycles, driving by belt direct from the motor shaft, had two separate pulleys—a large and a small one—attached on either face of the rear wheel, thus enabling the adjustment of speed before starting the vehicle, by belting in either one or the other. It is obvious, however, that, with a direct belt connection and a single reduction, it is far more convenient to regulate the speed and power output of the motor than to rely upon any form of variable gearing.

**Arrangement of the Motor.**—In the arrangement of the motor on a bicycle there has been a wide diversity of design. In some makes it has been supported on the back stays, between the pedal bearing and the rear wheel; in one make, on an extension of the back stays to rear of the wheel; in several makes it is supported against, or forms a part of the rear or saddle tube member of the "dimond" frame. The favorite position with most machines at the present time is on the forward member of the frame, in front of the pedal bearing, or on a tube arranged beneath, and suitably trussed to hold the weight.

**The Transmission.**—The method of driving is practically always by belt from a small pulley on the motor shaft to one of much larger diameter on the hub of the rear wheel. Most bicycles also have chains from the sprocket on the pedal bearing to another on the rear wheel, for use in starting or in case of disablement of the motor, and arranged to be thrown out by some form of ratchet or "coaster brake," as soon as the wheel is turned by the motor, thus having the pedals stationary in travel. The belts used for this purpose are generally twisted rawhide, and the length may be regulated, either by adjustable jockey pulleys or by unhooking the two ends and twisting or untwisting the strand to suit requirements. The use of hide belts is determined mostly by considerations of durability and safety, since the best-made chains are liable to snap at high speed, with the result, on a motor bicycle, of disabling the rear wheel, or of whipping up

violently against the rider. A hide belt could break under similar conditions without dangerous consequences.

Apart from the considerations just specified, the belt drive is the only really effective method of economical power transmission.

One or two bicycles, notably the Wolfmuller and Holder machines, have had two or four-cylinder motor direct connected to cranks on the rear axle. Another had the motor hung upon the axle, which it turned through an internal reduction gear. Both these arrangements, however, involve the disadvantage of losing power for the doubtful end of increasing speed, and have been entirely abandoned by modern constructors.

**The Auxiliary Apparatus.**—The other essential parts of a motor bicycle are the carburetter and gasoline tank, the battery, the induction coil and the oiling apparatus, all of which, from the necessary limitations of construction, are made as compact as possible. Several bicycles have used a combination of gasoline tank and carburetter, as in the De Dion cycles, the whole apparatus being included between the four tubes of the diamond frame above the pedal bearing; the motor being fed through a special mixing valve. The favorite apparatus at the present time seems to be some form of float-feed sprayer operating to draw the supply from the tank located conveniently under the upper member of the frame or over the rear wheel. One or two bicycles at least use simple mixing valves of the general type already described under the head of the James valve. With either sprayers or mixing valves the prime desideratum is the possibility of throttling or of regulating, as the only available means of controlling the speed of the vehicle. The battery consists generally of two or three dry cells in a suitable box, no case being at hand in which a magneto or dynamo was seriously attempted as a source of current. The ignition circuit in most machines corresponds in general features with the De Dion and other secondary spark arrangements already described, including an induction coil of standard pattern, and generally also, a condenser.

The lubricating apparatus is, of course, important, especially for supplying the cylinder and engine bearings, and in the majority of modern bicycles consists of an adjustable oil cup with

sight-feed attachment. The feed is thus rendered automatic, except for periodical regulations.

**The Framework and Wheels.**—The framework and wheels of motor bicycles are, of course, stronger and heavier than in foot-propelled machines. The tubes are made with thicker walls, and the joints are more securely reinforced. In several makes the end of security is further assured by struts and trusses, particularly at the fork on the steering post and at the place where the motor is hung. The diamond frame is practically universal, although several of the earlier types—notably the Wolfmuller and Lawson—used the drop frame. In the Holden bicycle the frame consisted of a single tube, joined to the steering post in front and bent downward to carry the drive wheel in a fork at the rear. The back stays were extended forward to hold the motor and other apparatus, and were further supported from the main tube by a dropping tubular member at front and rear. The pedals in this machine were geared to the forward wheel, as in old-fashioned velocipedes.

**Jar-Absorbing Devices.**—One great disadvantage in motor cycle construction is the practical difficulty of arranging any form of spring or cushion device to take the vibration of the motor. Several makes of machines include some spring arrangement in the saddlepost for easing the rider, but the framework must be built to endure the vibration of travel on rough roads, and at all speeds. The wear and strain, as may thus be seen, is immense. The only way to neutralize this element, moreover, is to provide the motor with extra heavy flywheels, in order to equalize the movement as far as possible. One excellent type of high-powered, high-speed machine, which has won exceptional records in a number of tests and races, has an extra large flywheel (between 18 and 21 inches, according to power), and the claims are that this "keeps the motor steady and does away with the heavy vibration in some high-powered machines." For machines intended for ordinary speeds such great additional weight is hardly necessary.

**Brakes for Motor Cycles.**—The question of brakes is an important one with motor bicycles and cannot be setlled off-hand

without some consideration of conditions. The principal difficulty involved in using a shoe brake of ordinary bicycle design on the forward wheel is that the sudden stop would result in even worse consequences—owing to higher speeds and greater weights—than the foot-propelled machine. There are also a number of constructional and practical difficulties involved in the attempt to use a positive brake on the rear wheel. In the majority of machines, therefore, the front wheel brake is omitted, and the braking of the rear wheel largely relegated to the compression of the motor, after the interruption of the sparking current. Several makes of bicycle, however, are now equipped with a type of friction roller brake on the forward wheel, consisting of two small rubber rollers, whose axes are set at a wide angle, so that their peripheries brush against either side of the tire, when pressure is exerted on the hand lever. The advantage of such a device is that, while the motion of the machine is effectually checked, the stop is not so sudden as to result in disastrous consequences to rider or motor.

The construction of a motor bicycle precludes the possibility of closely observing the operation of the parts in the course of ordinary travel. It is desirable, therefore, as has been indicated by several authorities, to have a stand of such shape that the machine may be hung free of the ground and set in motion, in order to afford opportunity to watch the motion and note any unevenness that may occur. The principal troubles to be diagnosed in this manner are those relating to the action of the sparking circuit, although it is frequently necessary to employ such means of discovering troubles with the moving parts.

# CHAPTER FORTY-NINE.

## ON THE CONSTRUCTION AND OPERATION OF BRAKES ON MOTOR CARRIAGES.

**General Requirements in Brakes.**—An important subject in connection with the construction and operation of motor vehicles relates to the brakes used for retarding the movement of the carriage when it is desirable to either come to a more or less sudden stop, or to hold the carriage stationary on the side of an incline. Several conditions are essential to the designing of brakes for motor carriages, among which we may mention ease and rapidity of operation and the maximum of braking effect, with the minimum of power exerted at the operating lever.

**Varieties of Construction in Brakes.**—There are two kinds of brakes in familiar use on vehicles of all descriptions: Shoe brakes, which operate by the pressure of the contact surface or shoe upon the periphery of the wheel tire, and drum brakes, which operate by tightening a band around a drum, either on the hub of the wheel or on the case of the differential gear. Both varieties are used to a considerable extent on motor vehicles, although most authorities agree that shoe brakes are unsuitable for use on wheels tired with pneumatic tubes. The reason given for this opinion is that the constricting effort due to pressing the shoe against the tire is, like the ordinary shocks experienced in travel, largely absorbed by the tire itself, with the result that it is liable to be rent or torn from its attachment to the rim. On the other hand, it has been asserted by at least one well-known manufacturer of motor vehicles that shoe brakes may be safely and satisfactorily used on pneumatic-tired wheels, provided the surface contact of the shoes extend over a sufficiently extensive arc to prevent the strain from being concentrated on small areas of the circumference. This authority asserts that he himself has used a motor tricycle for several years, the wheels of which are equipped with a shoe brake constructed according to his idea. The result is, he states, that the contact surface of the shoe has been worn much more rapidly than the tire surface, which seems to suffer very little, if any, more than would be the case with the

use of any other form of brake. Whether his experience in this regard would be borne out in general practice, it is not necessary to inquire, the fact being that nearly all motor vehicles at the present time operate with drum and strap brakes.

**Principles of Band Brake Operation.**—Among the advantages possibly to be alleged for the drum and band brake we may enumerate the facts that, with ordinary connections, they are much more readily operated and with much greater effect while on any showing involving a minimum of wear on the moving parts. As may be readily understood, the operation of the drum and band brake is a reversed application of the principle of torque, as already explained in connection with the electrical motor. As there explained, if the power acting upon a rotating shaft be equal to the weight of fifty pounds constantly applied, and the pulley attached to the shaft be twice the diameter of the shaft, the available power at the periphery of the pulley will be just one-half that exerted on the periphery of the shaft itself. This statement is equivalent to saying that if a rope carrying a weight of fifty pounds be wound about a pulley, whose diameter is one foot, mounted on a shaft, whose diameter is six inches, it will exactly balance a weight of one hundred pounds on a rope wound about the shaft. The constantly applied power of slightly over twenty-five pounds at the periphery of the pulley will be sufficient to rotate the shaft against a resistance of fifty pounds on the shaft. It thus appears that the braking power, applied around the periphery of the brake drum, is efficient in retarding the momentum of a forward-moving vehicle in very nearly the inverted ratio existing between the diameters of the drum, or pulley, and the rotating shaft to which it is attached. In the practical application of this principle, however, it is obvious that there must be very definite limits to the diameter of the brake drum, or pulley, beyond which it would be undesirable to go. According to the practice adopted by light motor vehicle manufacturers, the average diameters of brake drums range between eight inches and two feet, the principal item of variation in this respect being the weight of the vehicle itself.

**Beaumont's Formulæ for Brakes.**—It is possible to obtain a very efficient band brake on a very moderate diameter of drum,

owing to the fact, which need scarcely be mentioned, that the braking effort is never applied until the motive power is disconnected from the running gear. In a steam vehicle, the first act is to shut off the steam from the cylinder; in a gasoline vehicle, to throw off the main clutch; in an electrical vehicle, to open the circuit of the motor and batteries. The resistance against which the brake must then operate is found to be purely a consideration

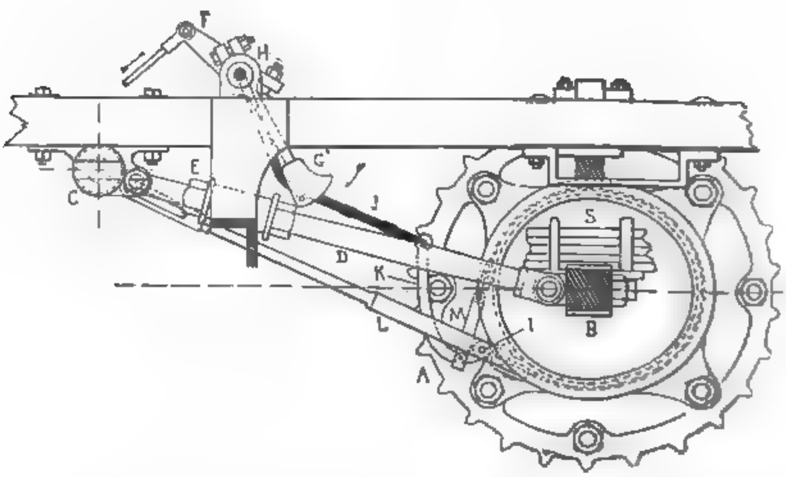



FIG. 382.—The Hub Brake and Operating Levers Used on the Panhard Carriages.—The arm, F, being pushed in the direction of the arrow, causes the arm, G, on the same pivot, H, to move in the opposite direction, as indicated by the lower arrow. Through this arm, G, runs the cable, J, as shown, which, pulling on the arm, K, pivoted at I, pulls the strap, shown by dotted lines around the drum, S. The other end of the strap attached to the short arm of the lever, K, is thus drawn toward the same point; a tight frictional bind being the result.

of the vehicle's weight, its velocity and the acceleration due to gravity. This principle is already stated by Mr. Beaumont, as follows:

"When it is necessary to determine the brake power to stop a vehicle of a given weight running at a given speed, in a given distance, and, by this means, arrive at something like due comprehension of the necessary parts brought into play to effect this stop, it must first be pointed out to those who overlook the fact, that the strain put upon a brake to effect a stop in a given distance increases as the square of the increase of speed; so that to stop a car running twenty miles per hour requires four times

the power necessary to stop it in the same distance when running ten miles per hour. Commonly, all calculations relating to the acceleration of masses at high speed are calculated on the basis of distance covered in feet per second, and hence the work or energy lodged in a mass having a given weight and moving at a given velocity in feet per second is given by the following expression:

$$K = \frac{W\ v^2}{2\,g}$$

in which *K* represents the work, or energy, lodged in the moving mass; *W* represents its weight; *v*, its velocity, expressed in

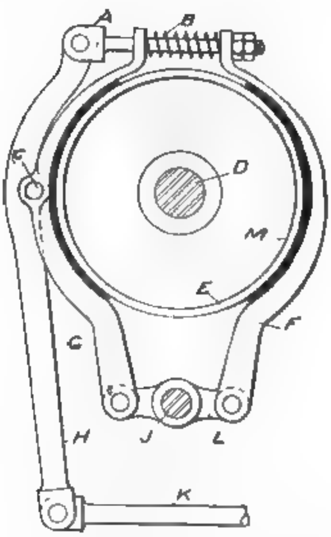



Fig. 383.

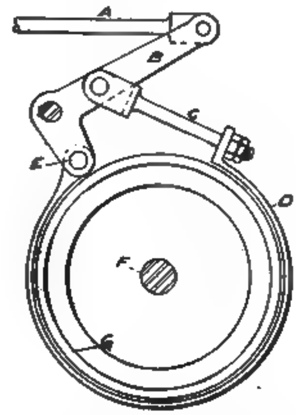



Fig. 384.

Figs. 383 and 384.—Two Forms of Constricting Band Brake. In the first figure, the drum, E, rotates on the spindle, D. Two shoes, F and G, joined to the link, L, pivoted at J, are pressed against the periphery of the drum, E, when the link, K, moves the lever, H, pivoted at C, so as to pull the arm, A, on F, by compressing the spring, B, normally holding them apart

In the second figure, the band, D, surrounding the drum, G, is drawn tight, when the link, A, operates the bell crank, B, thus producing a pull through its attachments at C and E.

feet per second, and *g*, the acceleration due to gravity, or 32.2 feet per second."

From the above formula, Mr. Beaumont proceeds to derive other essential elements, such as the efficient power necessarily

applied to stop a vehicle of given weight, in a given length of travel.

Reducing the expression for feet per second to miles per hour, according to the usual standard, and, assuming the weight of the vehicle to be one ton (of 2,240 pounds), he reduces the formula, as follows: One mile being 5,280 feet, and one hour, 3,600 seconds,

$$1 \text{ mile per hour} = \frac{5,280}{3,600} = 1.466 \text{ feet per second.}$$

Whence $\frac{W \ v^2}{2 \ g} = \frac{W \times (1.466)^2}{64.4} = \frac{W \times 2.15}{64.4} = W \times 0.0334.$

Then a vehicle weighing one ton, traveling at ten and twenty miles per hour, by the formula,

$$K = W \ V^2 \times 0.0334,$$

in which $V$ represents miles per hour, will be for 10 miles $2,240 \times 100 \times 0.0334 = 7,480$ foot pounds; for 20 miles $2,240 \times 400 \times 0.0334 = 29,920$ foot pounds.

**To Find Distance in Which Brakes Will Act on Vehicle's Speed.**—Then, taking $k$ as the coefficient of friction between the tires and road surface, which is approximately 0.60 for rubber tires; and taking $w$ as the proportion of the total weight carried by the wheels to which the brake is applied, which may be assumed to be 0.6 of the whole, the maximum distance required to stop the vehicle on the level, on an ordinary road, whose surface resistance is, supposedly, included in the expression, $k$, may be expressed by $l$, as follows:

$$l = \frac{W \ V^2 \times 0.0334}{k \ w}$$

Then, for a vehicle weighing one ton, tired with average rubber tires, traveling at a momentum of 10 and 20 miles per hour, respectively, we have:

$$l = \frac{7,480}{0.6 \times 1,344} = 9.3 \text{ feet at 10 miles, and}$$

$$l = \frac{29,920}{0.6 \times 1,344} = 37.1 \text{ feet at 20 miles;}$$

these distances representing the maximum, with a braking effect sufficient to cause the wheels to skid.

**To Find the Required Braking Pull.**—In order to find the necessary pull, $p$, on the brake band, the following formula is given:

$$p = k\,w = \frac{W\,V^2 \times .0334}{l},$$

which for one typical vehicle, moving at 20 miles per hour, gives,

$$p = \frac{29{,}920}{37.1} = 806 \text{ pounds.}$$

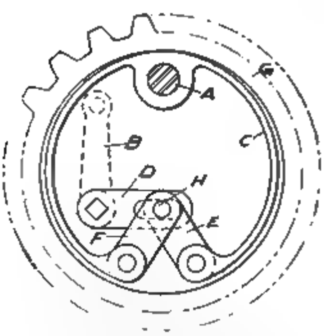



Fig. 385.

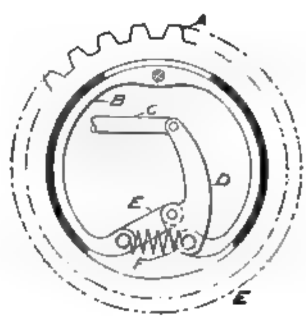



Fig. 386.

Figs. 385 and 386. Two Forms of Expanding Band Brake. In the first figure, the gear, G, has an internal bearing surface, within which is the band, C, pivoted at A, a point separate from G. The arm, B, of the bell crank, B D, being moved to the left, spreads apart the two links, E and F, connected to D at H, thus pressing both ends of the band, C, against the internal bearing surface of G, and producing the necessary braking friction.

In the second figure, the gear, A, similarly arranged with an internal bearing surface, contains the expanding band, B. When the link, C, is pulled, the lever arm, D, double-pivoted at E and F, causes the two ends of the band, B, to press against the internal bearing surface of A, thus creating friction. The spring shown normally holds the two ends of the band apart

**Varieties of Drum and Band Brake.**—As shown by accompanying illustrations, there are two general types of drum brake, the first consisting of a drum or pulley, around the circumference of which is a metal strap faced with leather, which is drawn tight whenever it is desired to furnish the resistance necessary to check the rotation of the shaft; and expanding band brakes, in which a similar metal strap, faced with leather or other suitable substance acts against the internal surface of a rotating drum or pulley. The former type is, however, at the present time the most usual construction, although the latter is seeing an increasing popularity.

In some forms of constricting band brakes, instead of a metal strap extending entirely around the drum, two shoes pivoted at a certain point, and having their inside faces faced with leather, are tightened against the drum by a suitable lever. In practically all forms of expanding band brake the band is attached to the outside frame, at one point of its circumference, and is suitably tightened by a toggle joint operated by a lever. This is the plan adopted in the several types shown in the accompanying illustrations.

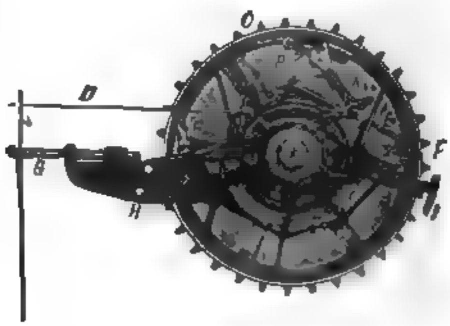



FIG. 387.—The "Duryea" Expanding Break. The two ends of the metal band are separated by the lever, A, and the adjusting screw, B, which is swiveled to the hinge, C. A forward pull on lever, A, through the chain pull, indicated by D, causes the two ends of the band to be thrust apart and bear against the inner surface of the sprocket. The extension spring, E, normally holds the band away from this friction surface. The two lugs, F F, attached to a spider hung on the axis of the sprocket, take the braking effort from the bottom of the band more into the line of travel. A framework, indicated at H and I, supports a leather guard covering both the chain and sprocket.

**The Care of Brakes.**—In successfully operating a motor carriage it is particularly essential that the brakes should be maintained in good working order. This involves that the levers and connections should at all times operate perfectly, and that no worn or loose bearings should be neglected. Furthermore, and most important, the friction surface between the band and the drum should be constantly and carefully guarded from oil deposits, which will certainly render the braking effort useless. If oil collects between the band and the drum surface it may be cut out with gasoline, and the parts then carefully wiped with a suitable rag.

## CHAPTER FIFTY.

### ON BALL AND ROLLER BEARINGS FOR MOTOR CARRIAGE USE.

**The General Uses of Rotative Bearings.**—The practical problems involved in the construction of bicycles and motor carriages have given a great popularity to ball and roller bearings for use in connection with almost every variety of rotating shaft. As we have already seen in several constructions mentioned in previous parts of this volume, ball bearings are used in a large variety of different devices, in order to allow of the greatest possible ease in turning with the smallest friction and wear. The most important use, however, for ball and roller bearings, in both bicycles and motor carriages, is on the axles of the road wheels. For this purpose, although ball bearings are eminently satisfactory on the wheel axles and pedals of bicycles, they are for a number of reasons unsuitable for the heavier weights and higher speeds of motor carriages. Accordingly roller bearings have taken their place almost exclusively in this connection.

**Rotating Supports vs. Sliding Surfaces.**—The principal object involved in using ball and roller bearings on bicycles and motor carriages is to secure economy of traction effort, with ease and rapidity of driving, as well as a minimum of starting effort at the beginning of travel. A few simple principles will serve to fully explain the reasons for this fact. When we have a plain wheel bearing, such as is used on ordinary horse carriages, consisting of a simple tapered boss, with a similarly shaped hollow axle-box rotating around it, there is a considerable effort necessary at starting from rest, a good proportion of the power being consumed in resisting the friction between the sliding surfaces. This resistance is very largely due to adhesion between the two sliding surfaces, due to cohesion of the lubricating oil or grease. As a matter of fact, it may be easily understood that the sliding action of two round surfaces, one within another, may be readily compared to the sliding of one plane surface upon another. The first difference in point of resistance and effort necessary to overcome inertia, as between two such surfaces, when sliding against

one another directly, and when some kind of rollers or rotating supports are interposed, is a matter of the commonest experience. The heaviest objects may be readily moved or slid along the ground when rollers are placed beneath them; also the heaviest loads when carried on wheels of suitable breadth and diameter may be handled with a degree of ease, increasing directly as the ideal conditions are approximated. This principle is the very one that is applied in the practice of substituting ball and roller bearings for ordinary plain bearings. Instead of two plane surfaces having rollers interposed, the two surfaces are given a rounded contour, the one being within the other, and the same rule of increased ease of relative movement applies.

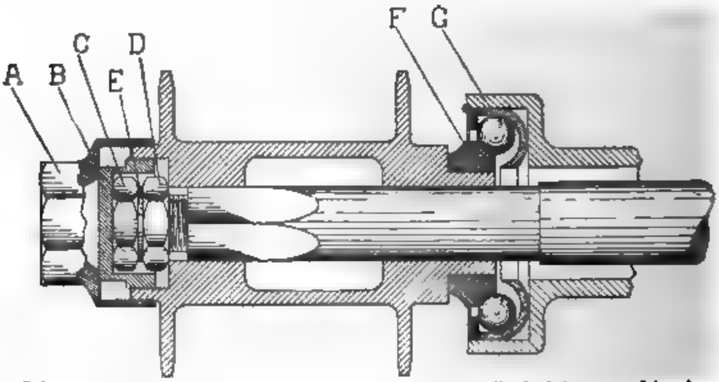



FIG. 888.—One Form of Driving Axle Using Ball Bearings. The hub is secured in place by the nuts and binders shown at A, B, C, D, E. At its inner extremity it carries a cone, F, which works on the ball race, G The hub is thus suspended on the ball race, which also acts to neutralize end thrusts.

**Rotative Bearings vs. Plain Bearings.**—The obvious reason for the superior traction qualities obtained by the use of both kinds of rotative bearings is that the friction and resistance between the relatively moving surfaces is so greatly distributed that it is reduced to a practically negligible quantity.

One of the most familiar evidences of loss in power through the friction of the sliding surfaces, in plain bearing wheels, is seen in the fact that the hubs speedily become loose, greatly to the detriment of balanced rotation of the wheels and waste of traction effort. With properly adjusted ball or roller bearings this result is indefinitely delayed, even where it is not entirely obviated, and the wheels on which they are used not only give the

best results in point of tractive efficiency, but also in the duration of their period of usefulness.

**Ball Bearings and Their Use.**—The ball bearing was originally introduced for use on bicycles, and contributed a goodly share to its success, principally for the reasons just specified. On the introduction of the motor carriage, it found a new field of usefulness, although, owing principally to the poor metal used for the balls and the defective designs of ball races, the roller

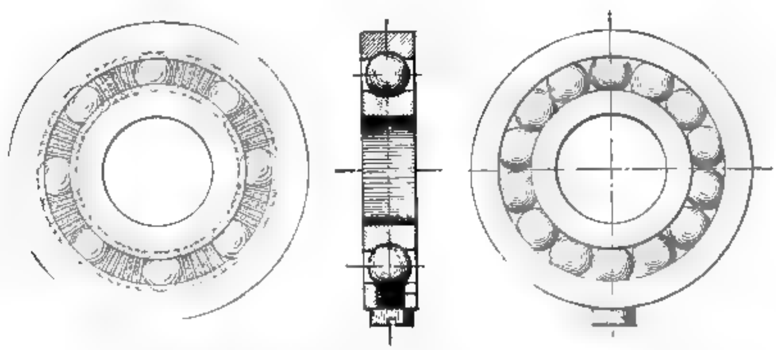


FIG 389 FIG. 390.

FIGS 389 and 390 —Radial Ball-races and Balls, showing most satisfactory method of mounting a ball bearing. Fig. 389 shows the so-called "silent type" of bearing, having the balls separated by felt-packed springs. Fig 390 shows the "full" type, in which the balls are in contact.

bearing enjoyed a greater popularity for several years. The reappearance of the ball bearing on the motor carriage is to be attributed largely, if not entirely, to fact that balls of superior and uniformly hardened steel have been introduced, which do away with the faults of case hardened steel—liability to crystallizing and crushing, due to inability to support a concentrated load on a single diameter. Formerly, considerable was said about the liability of balls to roll in opposite directions, thus producing friction and speedy wear, faults doubtless due to poor designs of the retaining cones and ball races.

The prevailing type of ball bearing at the present time is the so-called "radial," as shown in accompanying figures, in which the balls are inserted between an internally and an externally

grooved ring. For the best results only a single row of balls is used in a journal, and all uncertainty and irregularity in supporting the load are thus eliminated. The radial ball bearing is also capable of taking up moderate end-thrust, although with large end thrust a special thrust bearing, having the balls running in face grooves between two plates, is used. The type of bearing thus described is capable of showing a nearly uniform friction coefficient.

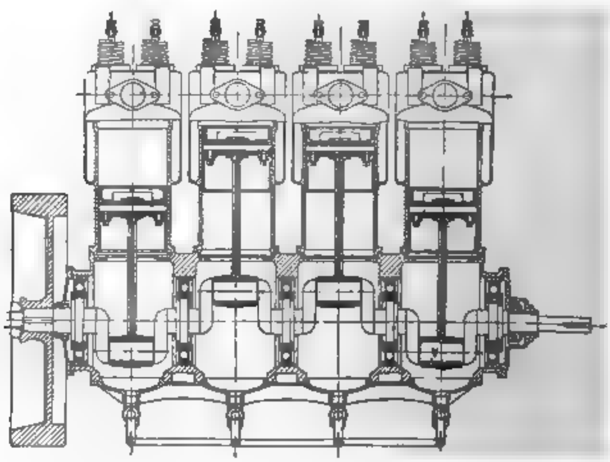


FIG. 301.—Four-cylinder Gasoline Engine, showing the radial ball bearings on the crank shaft.

**Roller Bearings and Their Use.**—Very largely on account of the defects in the earlier types of ball bearing, roller bearings were for several years used almost exclusively on motor carriages. As has been stated by a prominent manufacturer of roller bearings, we have it that "for heavy weights it would seem that a greater rolling surface must be obtained before we can have a successful bearing, and yet, combined with this greater rolling surface, there must be a purely rolling action to eliminate the wear that results from rubbing and crystallization."

As stated by a noted authority, the peculiar advantage of the roller bearing lies in the fact that in the ideal conditions there is no relative sliding, and, therefore, theoretically, no friction. As also stated by him, however, there are several difficulties in the

way of obtaining the theoretically perfect conditions in practical operation. These are: (1) the concentration of the load upon points; (2) the almost insurmountable difficulty of obtaining truly circular cylindrical rollers; (3) the friction on the surfaces of the rollers themselves; (4) the difficulty of adjustment; (5) the lack of parallelism when the rollers are slightly worn; (6) the difficulty of providing for end thrusts or side pressures; (7) the blows and shocks resulting when wearing has occurred on the surfaces of the rollers. He further explains that to any extent whatever, however small, that the surface of contact deviates from the theoretical or geometrical line, the action between the two surfaces deviates from the theoretically perfect rolling contact, involving sliding or frictional contact proportionate to the deformation of the roller.

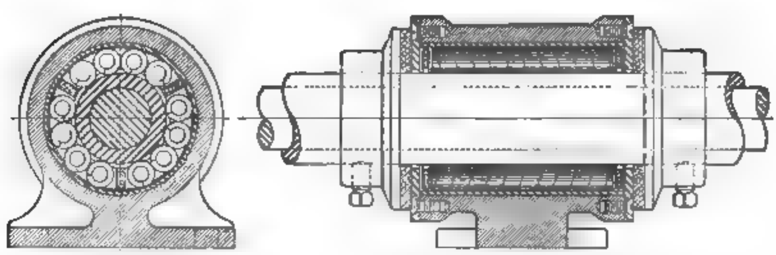


FIG. 392 —The "Hyatt" Flexible Roller Bearing, which consists of strips of steel rolled into coiled springs, forming a strong, though elastic, support, and capable of taking some end thrust.

**Constructional Points on Roller Bearings** —Given the best possible process available to the practical machinist for the needs of adequately shaping and hardening rollers, the problem of the best construction becomes almost entirely one of proper assembling of the several parts. As shown by the accompanying illustration, the usual method of mounting roller bearings is to enclose them in a suitable case, in which the several cylindrical rollers are separated, so that, rotating on their own axes, their surfaces do not come into contact. It is a very usual practice to include end thrust ball bearings at the extremities of the roller cylinders, so as to still further reduce the wear and friction incident on the rotation of the several cylinders.

One of the most excellent types of roller bearing for motor carriages is the "American" roller bearing, which, as shown by

the accompanying illustrations, consists of a set of main rollers intended directly to sustain the weight, and running in races on the hub and on the axle. These main rollers are separated and guided by intermediate separating rollers, whose office is solely that of separating and guiding. These separating rollers are confined between the centres of the main rollers and overlap their ends, their action being entirely rolling. The supports of these separating rollers are had in three rings held in place by the flange ends of the separators and running in narrow beveled grooves in the separators and in the fixed caps which enclose the entire mechanism. The rolling parts are so arranged that the

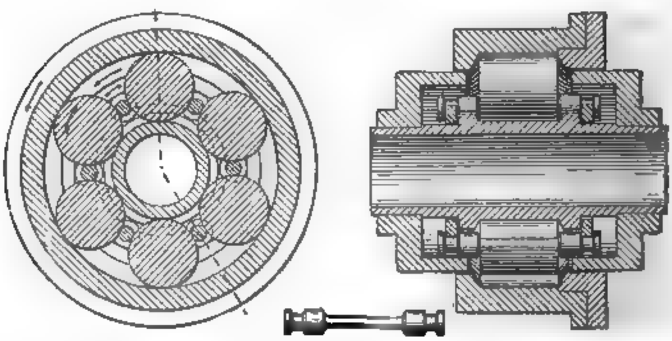


FIG 393.—Sectional Diagrams of the "American" Roller Bearing. These bearings are beveled at the ends, as indicated, the bevels taking up the end thrusts, and are separated by smaller rollers, one of which is shown below the larger figures. These separating rollers do not come into contact with the rotating axle.

separators engage their supports in perfect harmony with the main rollers, traveling just fast enough to keep up with them in going about the axle, thus avoiding both dragging and pushing.

In this type of bearing the end thrust is entirely taken by bevels, on the principle of the flanges on car wheels, this construction involving that there is no rubbing friction; the action between the ends of the roller and bevels, being purely a rolling one, they are thrust against each other. As claimed by the manufacturers, the separators hold the main rollers far better than any cage could, while the wear upon them is practically negligible, the result being that the main rollers are never allowed to twist around, as is frequently the case in caged bearings.

## CHAPTER FIFTY-ONE.

### ON THE NATURE AND USE OF LUBRICANTS.

**Of Lubricants for Various Purposes.**—One of the most important considerations in connection with the operation of a motor vehicle, of any power, relates to the proper lubrication of the moving parts. As is perfectly evident on reflection, it is necessary that all such parts should be supplied with oil or lubricating grease, but it is also a fact, not so well understood, that different kinds of lubricant are necessary to the different kinds of mechanisms.

**Of Lubricants for Gasoline Engine Cylinders.**—Every reliable dealer in lubricants has a specially prepared grade of oil for a gas engine cylinder, and still another for use in the cylinder of a steam engine, and all agree to the statement, that the kind of lubricant suitable in one case is wholly useless in the other. The primary reason for this distinction is that, as we have seen, the cylinder of a gas engine operates under a far higher temperature than is possible even in a steam engine, and consequently the oils intended for use in the former case must be of such a quality that the point at which they will burn and carbonize from heat is as high as possible. Furthermore, it is essential in a gas engine cylinder that the oil should be constantly supplied, and for the purpose of properly meeting this requirement a number of different kinds of dripping and filtering oil cups have been devised and put into practical use.

**Requirements in Gas Engine Lubricants.**—As has been repeatedly pointed out by gas engine authorities, the apparently long period spent in finally perfecting the motor was due almost entirely to the fact that the subject of proper lubrication was not fully understood. With the ordinary oils, which are sufficiently suitable for use in the steam engine cylinder, it was impossible to obtain anything like a satisfactory speed and power efficiency, and only when the superior properties of mineral oils were better understood was the present high degree of perfection in any

sense obtainable. Even to the present day the question of proper lubricants for gas engines is most essential, and, as has been pertinently remarked, "the saving of a few cents per gallon in purchasing a cheaper grade of oil for this purpose is the most expensive kind of economy imaginable." The general qualities essential in a lubricating oil for use on gas engine cylinders include a "flashing point of not less than 360°, Fahrenheit, and fire test of at least 420°, together with a specific gravity of 25.8 and a viscosity of 175."

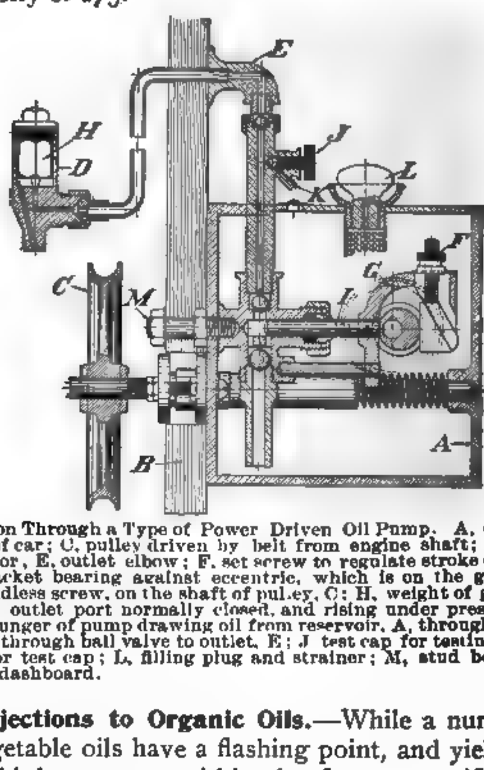



FIG. 394.—Section Through a Type of Power Driven Oil Pump. A, oil reservoir; B, dashboard of car; C, pulley driven by belt from engine shaft; D, gravity valve on distributor, E, outlet elbow; F, set screw to regulate stroke of plunger, I; G, plunger bracket bearing against eccentric, which is on the gear operated by worm, or endless screw, on the shaft of pulley, C; H, weight of gravity valve, D, for holding outlet port normally closed, and rising under pressure of oil from pump; I, plunger of pump drawing oil from reservoir, A, through ball valve, and expelling it through ball valve to outlet, E; J test cap for testing flow of oil; K, oil outlet for test cap; L, filling plug and strainer; M, stud bolt for securing machine to dashboard.

**Some Objections to Organic Oils.**—While a number of animal and vegetable oils have a flashing point, and yield a fire test sufficiently high to come within the figures specified, they all contain acids or other substances which have a harmful effect on the metal surfaces it is intended to lubricate. In addition to this, their tendency to gum or congeal under certain conditions of temperature or pressure render them unfit for the purpose of gas engine lubrication.

**The Use of Graphite as a Lubricant.**—Many authorities strongly recommend the use of powdered or flaked graphite in the cylinders of explosive engines for the reason that this substance is one of the most efficient of solid lubricants, especially at high temperatures. It has been found especially useful in some steam engine cylinders and in general on the bearings and moving parts liable to become overheated. According to sev-

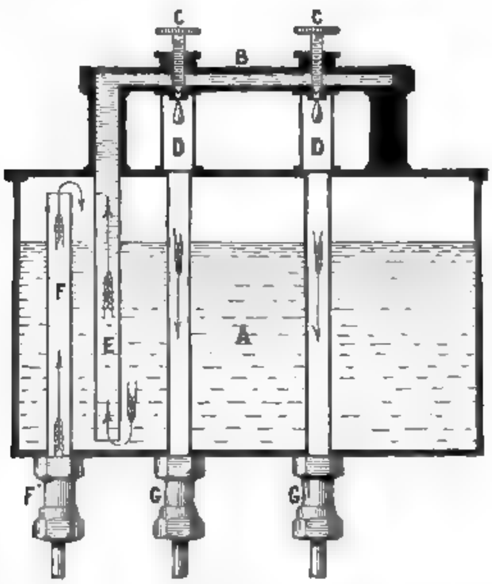



FIG. 395. Typical Force-feed Lubricator, operating by air or gas pressure, instead of a pump. The parts are: A, oil reservoir; B distributing pipe; C, C, valve screws for regulating flow of oil to parts, through leaders, D and D: E, standpipe through which oil is forced by air pressure; F, standpipe admitting gas from crank case of engine; F', union for pipe from crank case; G, G, unions for pipes to various parts of the machinery.

eral well-known authorities, it is well adapted for use under both light and heavy pressures when mixed with certain oils. It is also especially valuable in preventing abrasion and cutting under heavy loads and at low velocities.

In using graphite as a lubricant, it is positively essential to remember one thing: It is, as said, very useful *for certain purposes,* when mixed with some liquid oil lubricants. However, it is impossible to use it in connection with oils that are to be filtered through the small orifices of constant feed oil cups, as on

the cylinders and bearings of engines. The reason for this is that it will not flow through small holes, even when mixed with very thin oil; and the very cooling of a bearing will cause the graphite, mixed with oil, to clog up the oil hole to an extent that may not be remedied by the reheating of the bearing, after the stoppage of the lubricant. On the same account, it is essential that the diameter of the oil conduit to any moving part be ascertained to be of suitable shape and proportions before the use of any solid lubricant is attempted.

**The Tests and Qualities of Lubricating Oils.**—It is perfectly possible to use an oil having a fire test at the point already mentioned in a gas engine cylinder whose temperature at explosion is nearly four times greater, because with a properly ad-

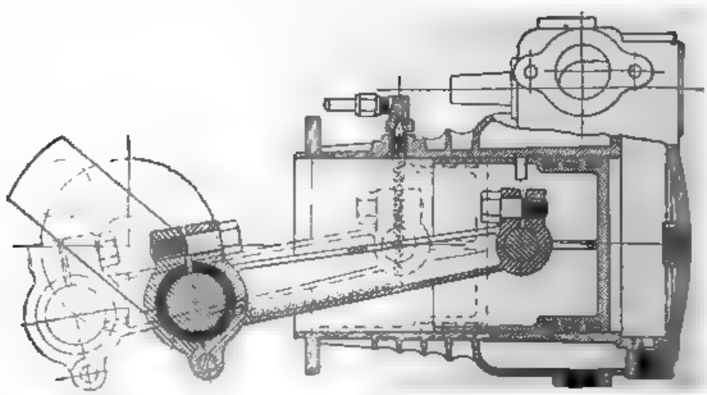


FIG. 396. Horizontal Cylinder Oiled by Force-feed Oiler Distributor. The piston is oiled when passing under oil port, as shown by the dotted outline. The connecting rod is longitudinally grooved on the upper surface, so as to carry oil to the bearings.

justed water circulation the burning and carbonization of the oil is constantly prevented. The heat-absorbing action of the jacket water is also efficient in retaining at the required point the viscosity of the oil—which is to say, the quality of dripping at a certain ascertained rate through a narrow aperture under pressure. This quality virtually refers to the thinness of the oil. A well-known manufacturer of lubricating oils for gas engine cylinders well states the ideal qualities to be sought, as follows: "There is no danger of this oil burning or smoking in the cylinder and thus causing a carbonaceous deposit, which so seriously

interferes with the proper running of the engine. We have repeatedly known of this oil, when put into a cylinder which had not been properly cleaned, cutting out the carbonaceous matter that had accumulated from the use of an inferior oil, after which the cylinder would remain clean and polished by the action of the oil alone." Combined with these ideal elements, the claim is made that this particular variety of oil has a very low "cold test," with the very necessary insurance against congealing, and consequent delay and inconvenience in starting the engine. Its resistance to heat is also placed at such a figure that it will not become unusually thin as will some qualities of oil, the reason being that its viscosity is maintained at the desired point.

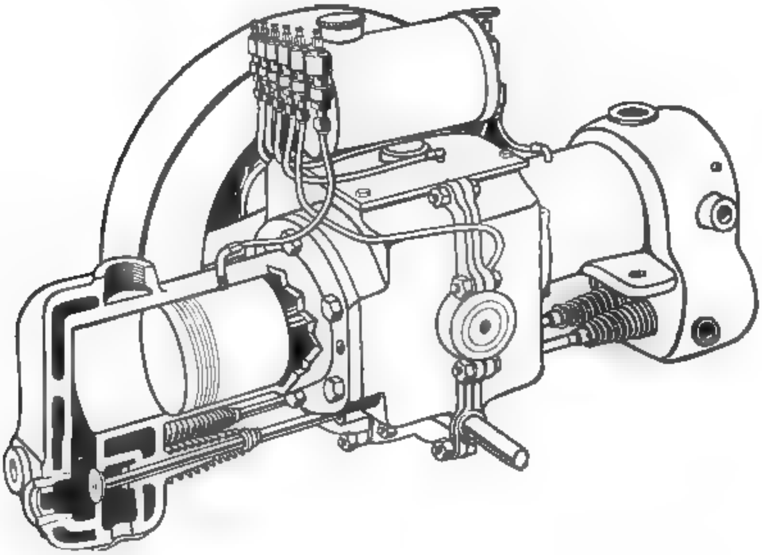


FIG. 397 Section of the Ford Double-Opposed-Cylinder Horizontal Engine, showing oil leads to the various points from the lubricator operated by compressed air from the crank case.

In choosing lubricants for any of the moving parts of a self-propelled road vehicle it is especially essential to see that the quality of resisting temperatures, both high and low, without change of useful consistency, should be present. An oil that will congeal at ordinary low temperatures, or become thin at ordinary high temperatures, is, of course, entirely unsuitable for this

purpose. Furthermore, the quality of flowing freely from well-adjusted oil cups should be assured, since the high speed of automobile engines engendering a constant vibration, affecting more or less the adjustment, involves that the oil supplied should be a subject of constant solicitude. To state the matter in a few words, all competent authorities seem to agree that the conditions of automobile operation require the use of mineral oils on all moving parts and the avoidance of any mixture with animal or vegetable oils, which, although frequently used in stationary engines, cannot but result in inconvenience, not to say disaster, in automobile practice.

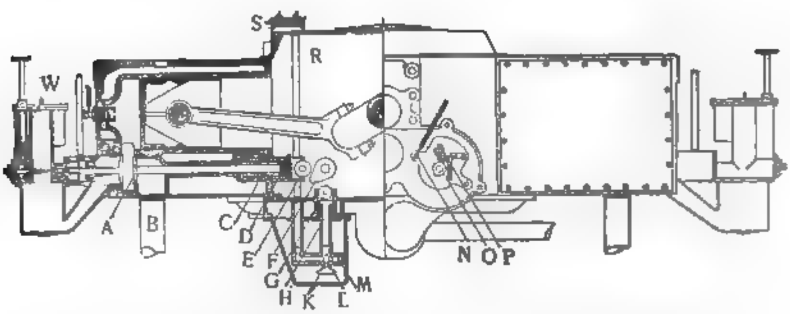



FIG. 398.—Sectional Diagram of the Winton Two-cylinder Horizontal Engine, showing details of valves and oil pump. A, exhaust valve; B, pipe leading exhaust gases to muffler: C, exhaust valve spring; D, set screw: E roller engaging cam, F, which also engages with roller, G, and operates oil pump piston, H; K, filter for oil forced from pump; L, ball valve on oil pump; M, by-pass for excess of oil from pump; N, primary wire from coil to breaker box; O, spark cam; P, contact adjusting screw, R, vertical pipe for oil forced from pump; S, oil conduit and adjusting screws to regulate flow of parts: W, pin projecting from float in carburetter. This cut also shows the shape and position of the carburetters, of the inlet valve air-line relief pipe, and the sparking plug. The hand wheels and spindles rising from the carburetters serve to regulate the maximum output of gasoline at each suction stroke.

Since most manufacturers of motors and vehicles furnish moderately full directions for dealing with the question of lubrication, many of them offering for sale brands of oil which have been carefully tested by themselves, it will be hardly necessary to add more to the principles already laid down. If the automobile driver constantly bears in mind the fact that an oil suitable for one portion of his machinery is not of necessity suitable for every other, and will observe the conditions essential to maintaining the oil used at its proper consistency, he will have little trouble upon this score.

**Points on Lubrication.**—The first important consideration involved in preparing a carriage for a run is to see that the moving parts are properly lubricated. Every carriage or motor is sold with directions for providing for this necessity, the rate of oil consumption and the quantity being specifically designated. The

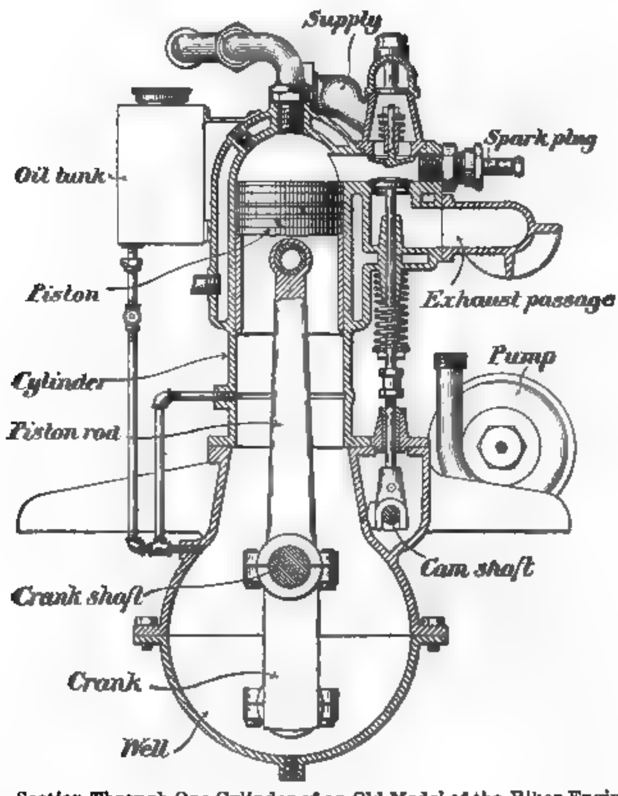



FIG. 399. Section Through One Cylinder of an Old Model of the Riker Engine, showing gravity oil feed and splash lubrication. Oil flows from the oil tank to the crank case, and is splashed to the piston sweep by the end of the connecting rod. Excess is caught in the peripheral groove at the end of the piston sweep and returned to the crank case.

principal parts which it is particularly necessary to keep thoroughly oiled are the cylinder pistons, the bearings of the crank shafts and fly-wheels, the differential gear drum and the change speed gearing.

Since on most well-built motors and carriages the moving parts

are supplied with lubricating oil by means of sight feed oil cups. of familiar design, it is necessary to do no more than to see that the required level of oil is always maintained. As specified by many motor carriage authorities, it is desirable to thoroughly examine and replenish the oil supply in the adjustable feed cups at the end of about every thirty miles of run. Another consideration of importance in this particular is that before replenishing the supply of oil to such parts as the crank case or the differential gear, the old lubricant should be thoroughly evacuated by means of the vent cocks supplied in each case. The reason for this is that, after a run of from twenty to thirty miles, the oil in the moving parts is apt to be largely contaminated with dust and other impurities, which tend to interfere with its usefulness as a lubricant.

**Oil Pumps and Circulation.**—With the use of high-speed gasoline engines, it has been found necessary to use a forced circulation of the oil in order to completely lubricate the interior of the cylinder. The most usual method with high-powered multiple-cylinder engines is to employ a positively geared pump to force the oil through adjustable sight-feed conduits to the various moving parts. Such pumps, operating in ratio to the speed of the engine, of course supply lubricant more rapidly as the number of revolutions increases, and slow down as they decrease. Thus, a perfect supply is maintained, as required, on the one hand, and flooding is prevented on the other. There are several efficient types of oil pump on the market, all working on the same principle of forcing the oil to the moving parts in such volumes as may be determined by the adjustment. One or two inventors have produced devices of this kind operated by compressed air forcing the oil out of a tank, the degree of compression being determined by the speed of the engine operating the air pump.

# INDEX.

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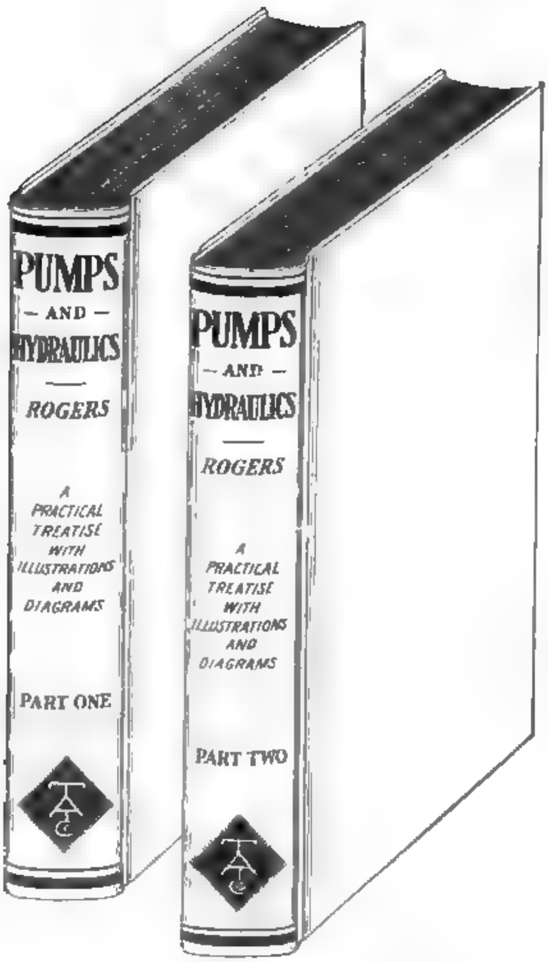


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The divisions of Part Two are represented by the following headings. Each subject is fully treated and illustrated.

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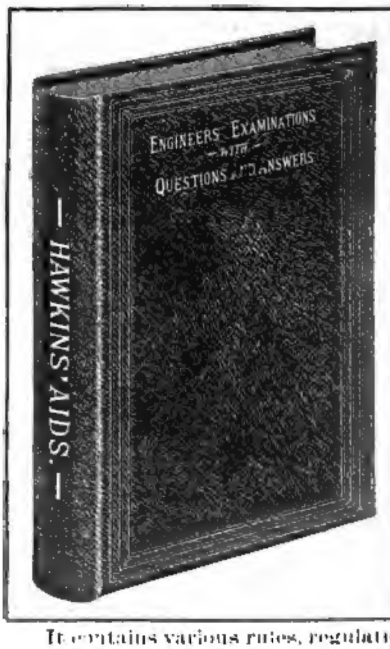
"It should always be remembered that an engineer is paid for what he knows rather than for what he performs, and above all else for his knowledge of the first principles of steam and electric engineering."

THIS work is an important aid to engineers of all grades, and is undoubtedly the most helpful ever issued relating to a safe and sure preparation for examination. It presents in a condensed form the most approved practice in the care and management of Steam Boilers, Engines, Pumps, Electrical and Refrigerating Machines.

It gives a few plain rules of arithmetic with examples of how to work the problems relating to the safety valve, strength of boilers and horse power of the Steam Engine and Steam Boiler.




The main subjects treated, upon which are given detailed information with questions and answers, are as follows:

The Steam Boiler, Boiler Braces, Incrustation and Scale, Firing of Steam Boilers, Water Circulation in Boilers, The Steam Engine, Engine and Boiler Fittings, Pumps, The Injector, Electricity and Electric Machines, Steam Heating, Refrigeration, Valve Setting, etc., etc.

It contains various rules, regulations and laws of large cities for the examination of boilers and the licensing of engineers. It contains the laws and regulations of the United States for the examination and grading of all marine engineers.

It gives a short chapter on the "Key to Success" in obtaining knowledge necessary for advancement in engineering. This is very important.

The book gives the underlying principles of steam engineering in plain language, with very many sample questions and answers likely to be asked by the examiner.

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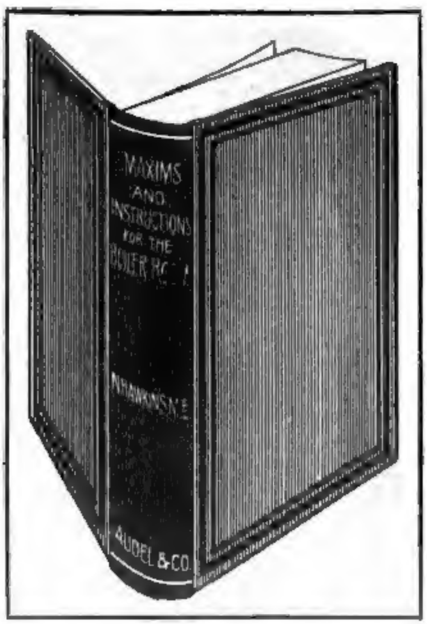
# Hawkins' Steam Boilers, $2

THIS book is a complete work of instruction on boiler-room practice and will be found of great help to firemen, engineers and all others who wish to learn all about this important branch of Steam Engineering.

It gives a treatise on materials, coals, wood, coke, and oil and gas, fuels, etc., their composition, properties, combustive value, also on combustion and evaporation.

It gives the practical rules to be observed in firing with various fuels, management of steam boilers, prevention of foaming in boilers; tools and fire irons; covering of stationary, marine and locomotive boilers.




It enumerates sixty important points or cautions to be observed in the proper management of boilers and care of boiler room.

It contains a description of and full treatise on stationary, marine, and locomotive boilers, and the historical development of boilers; specifications for boilers; riveting, bracing; rules for finding pressure or strain on bolts.

It gives inspectors rules relating to braces in steam boilers. Also rules and tables for calculating areas and steam and water space of boilers.

It treats on boiler tubes, construction and drawing of boiler sections; defects and necessary repairs; inspection of steam boilers; mechanical stokers' corrosion and scale, boiler compounds, feed water heaters, injectors, pumps, boiler settings; pipes and piping; steam heating, chemistry of the furnace; boiler making; plumbing, and hundreds of other useful subjects.

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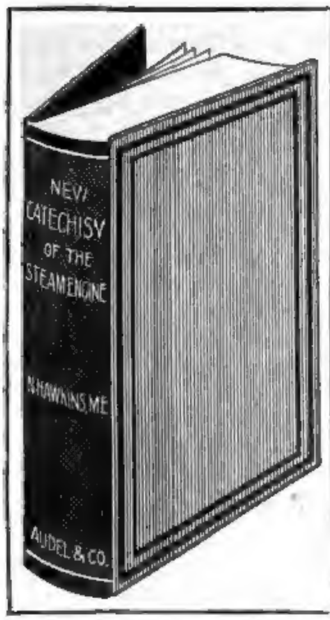


Introduction; The Steam Engine; Historical Facts Relating to the Steam Engine; Engine Foundations; The Steam Piston; Connecting Rods; Eccentric; Governor; Materials; Workmanship; Care and Management; Lining up a Horizontal or Vertical Engine; Lining Shafting; Valve Setting; Condensers; Steam Separators; Air, Gas, and Compressing Engines; Compounding; Arithmetic of the Steam Engine; Theory of the Steam Engine; Construction.

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